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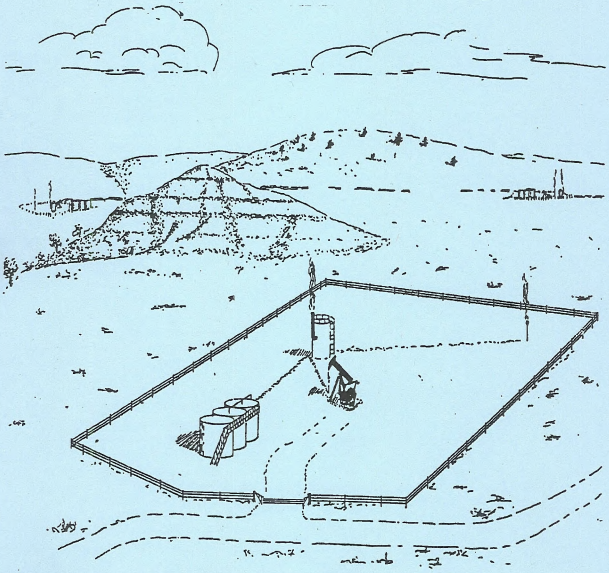
WILLISTON BASIN REGIONAL AIR QUALITY STUDY



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WILLISTON BASIN REGIONAL AIR QUALITY STUDY

VOLUME I

Final Report, June 1990

(Cooperative Agreement MT950-CA7-005)

Prepared by

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A Cooperative Project of

U.S. Department of the Interior
Bureau of Land Management
Dickinson, North Dakota

North Dakota State Department of Health
and Consolidated Laboratories
Bismarck, North Dakota

Montana State Department of Health
and Environmental Sciences
Billings, Montana

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EXECUTIVE SUMMARY

The Williston Basin Regional Air Quality Study was conducted to assess the air quality impact of oil and gas development in western North Dakota. The Study addressed air quality impact of oil and gas production facilities for existing and foreseeable-future scenarios for selected oil and gas fields in western North Dakota. Emissions inventories were prepared, and air quality models were applied to project the impact of SO_2 and H_2S emissions in these fields with respect to applicable ambient air quality standards and PSD (Prevention of Significant Deterioration) increments. The Study also included investigation of strategies to mitigate exceedances of ambient air quality standards or PSD increments, in areas where such were predicted.

The Study was conceived and implemented in response to concerns regarding the air quality effects of continued oil and gas development in the Williston Basin. State and Federal agencies, responsible for regulating or monitoring oil and gas development and associated air quality impact, required more information on air quality status for planning and management decisions. Little such information was available. Thus, a cooperative agreement was effectuated among several agencies to accommodate the Williston Basin Regional Air Quality Study. Participating agencies include the North Dakota State Department of Health and Consolidated Laboratories, U.S. Department of the Interior Bureau of Land Management, Montana State Department of Health and Environmental Sciences, and U.S. Department of Agriculture Forest Service.

The Study procedure began with development of existing and foreseeable-future emissions inventories for the entire Study area. Twelve oil and gas fields in western North Dakota were selected as subjects for the Study, and dispersion models were applied to assess air quality impact in these fields and in four nearby PSD Class I areas. Next, modeling results were interpreted using tabular and graphical methods. Potential mitigating measures were investigated to address exceedances of ambient air quality standards or PSD increments for fields where they were predicted. Finally, this report, describing Study methodologies and results, was prepared.

The Williston Basin Regional Air Quality Study reflects a substantial effort and provides considerable regional information regarding the potential air quality impact of oil and gas production in North Dakota. Study results suggest that:

- Existing air quality with respect to ambient air quality standards for SO_2 and H_2S is generally good. Though exceedances of ambient air quality standards were predicted for some subject oil and gas fields, the areal extent of exceedance tended to be very localized.

- Existing air quality with respect to PSD Class II increments for SO_2 is generally good. Again, exceedances of PSD Class II increments were predicted for some subject fields, but the areal extent of exceedance tended to be localized.

- Existing air quality with respect to PSD Class I increments for SO_2 is not favorable. Exceedances of Class I increments were predicted throughout three of the four Class I areas.

- Addition of projected foreseeable-future wells to subject fields does not substantially change modeling results with respect to ambient air quality standards for SO_2 and H_2S. The effect on PSD Class II increments for SO_2 was somewhat greater (exceedances predicted in two additional fields).

- Before additional development of oil and gas fields can actually take place (except for new well installations with zero emissions potential), implementation of mitigating measures to address predicted existing exceedances of ambient air quality standards and PSD increments will generally be required. Mitigating measures to correct existing exceedances of ambient air quality standards and PSD Class II increments appear feasible. To address predicted exceedances of PSD Class I increments, however, the North Dakota State Department of Health and Consolidated Laboratories will have to consult applicable Class I area Federal Land Managers.

In general, Study results suggest that additional development of oil and gas fields in western North Dakota is possible provided that existing exceedances of ambient air quality standards and PSD increments are addressed, and provided that such development is carefully planned and managed. Development of new wells with zero emissions potential (e.g., well tied-in to gas-gathering network and treater fired on propane) would, of course, be unrestricted from the air quality management standpoint.

ACKNOWLEDGMENTS

The Williston Basin Regional Air Quality Study was truly a cooperative effort. The authors appreciate the overall involvement of all participating agencies, as well as the individual contributions of their representatives.

From the North Dakota State Department of Health and Consolidated Laboratories, very special thanks are extended to Daryl Uran. Without Daryl's expert and thoughtful input on a multitude of oil and gas production issues, this Study would not have been possible. Thanks also to Tom Bachman for his contributions in writing this report, and to Dan Harman for his assistance in preparing report figures. The expeditious efforts of Sherri Jahraus and Sandra Kraft in typing the manuscript of the report are also appreciated.

From the Bureau of Land Management, Dickinson, special thanks are extended to Russell Pigors for his input and overall coordination of the project. Thanks also to Gene Campbell and Rick Hotaling for their projections regarding the foreseeable-future production scenario which was addressed in this Study, and for their advice on other issues.

Thanks are due Jim Hughes of the Montana State Department of Health and Environmental Sciences for his efforts in assembling model input data for Montana oil and gas wells.

The financial support of the Bureau of Land Management and U.S. Forest Service is appreciated. Thanks also to the State of North Dakota for making necessary computer facilities and data bases available for this Study.

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1. INTRODUCTION

A study has been conducted to determine the air quality impact of oil and gas development in western North Dakota. This Study, known as the Williston Basin Regional Air Quality Study or Williston Basin Study (WBS), was implemented to assess the existing and foreseeable-future air quality consequences of oil and gas production activities for selected oil and gas fields in western North Dakota. Air quality models were used to project the impact of SO_2 and H_2S emissions in these fields with respect to applicable ambient air quality standards and PSD (Prevention of Significant Deterioration) increments. The Study also included investigation of potential regulatory strategies to mitigate exceedances of ambient air quality standards or PSD increments, in areas where such were predicted.

The Williston Basin Study provides considerable regional information regarding the potential air quality impact of oil and gas production in western North Dakota. Such information was previously available only from localized modeling studies, or from limited air quality monitoring. Williston Basin Study results should benefit those agencies responsible for regulating air quality, or monitoring oil and gas development in North Dakota.

The Williston Basin Study included the following components:

1) Development of an emissions inventory (existing and foreseeable-future) for the entire Study area.

2) Selection of twelve oil and gas fields in western North Dakota as subjects for the Study.

3) Air quality modeling of twelve subject oil and gas fields, and four nearby PSD Class I areas.

4) Assessment and interpretation of model results.

5) Investigation of mitigating measures to address exceedances of ambient air quality standards or PSD increments for fields where they were predicted.

6) Preparation of technical report (this report).

Air quality modeling methodologies employed in the Study were based on EPA (U.S. Environmental Protection Agency) guidance, and on previous experience acquired by the North Dakota State Department of Health and Consolidated Laboratories in modeling oil and gas facilities.

1.1 Impetus for Study

The North Dakota State Department of Health and Consolidated Laboratories (NDSDH) and the Bureau of Land Management (BLM) jointly determined that the Williston Basin Study was necessary. The NDSDH's Environmental Health Section has regulatory authority for management of the air resource in North Dakota, which includes permitting of new pollution sources, and maintenance of all ambient air quality standards and PSD increments. The BLM is responsible for the administration of the Federal mineral estate and the policies, plans, uses, and decisions of the public lands within the Williston Basin area of western North Dakota. Permitting of energy development by the BLM for those Federally

administered lands (surface and subsurface) constitutes a Federal action which requires National Environmental Policy Act (NEPA) documentation of the impacts, including air quality impacts. Thus, both the NDSDH and BLM had concerns regarding the air quality consequences of energy development in the Williston Basin.

Despite concerns about the air quality impact of increasing SO_2 and H_2S emissions from oil and gas fields, the NDSDH (prior to 1987) did not have the necessary resources or regulatory framework in place to deal with the permitting and management of oil and gas production facilities in North Dakota. During the late 1970's and the 1980's the NDSDH was hard pressed to meet the demands of air quality permitting activities for major emission sources associated with the increases in energy development, and thus could not attend the management of numerous minor emission sources associated with oil and gas production. Further, the dispersion modeling analyses necessary to assess air quality impact of oil and gas facilities were not economically feasible because of the large number of such facilities (cost of executing model is proportional to number of sources).

During the late 1980's the demands associated with permitting of major sources receded and, in 1987, the NDSDH adopted rules (regulations) specific to the permitting of oil and gas facilities (see Section 2.2). These rules included establishment of a registration system which requires well operators to submit information concerning equipment configuration and production rates for the well installation. The rules provided a means to collect information to be used to assess potential air quality impacts; however, the rules did not provide for routine dispersion modeling analyses for each well.

In 1988, the NDSDH acquired a desktop computer capable of executing dispersion models nearly as fast as the mainframe computer that had been previously utilized. The significance of this acquisition was that dispersion models could now be applied to oil and gas problems involving numerous sources, because cost of execution was no longer a factor.

The acquisition of the sophisticated desktop computer coupled with a new source of emissions data provided the NDSDH with some of the necessary resources to conduct sophisticated dispersion modeling analyses of air quality impact in oil and gas fields. It was therefore concluded by the BLM and the NDSDH that the time was appropriate for a comprehensive, large-scale modeling study of air quality impacts associated with oil and gas processing activities throughout western North Dakota.

1.2 Cooperative Agreement

The BLM first approached the NDSDH in 1987 regarding a potential air quality analysis. To accommodate its resource planning responsibilities, the BLM suggested that the proposed Study include an assessment of both existing and foreseeable-future air quality impacts of oil and gas production activity. The BLM further suggested that the Study include an investigation of mitigating measures which could be employed to improve air quality if exceedances of ambient air quality standards or PSD increments were predicted. Thus, the Study was intended to foster continued, carefully managed oil and gas development.

The NDSDH agreed that, with input of certain resources by the BLM, a comprehensive Study of oil and gas facility impact on air quality in western North Dakota was feasible and should be conducted, and should include assessment of foreseeable-future air quality impact and mitigating measures. After a series of meetings and other correspondence between the BLM and NDSDH, a "cooperative agreement" was

formulated to set forth responsibilities for both agencies to accomplish a cooperative air quality study. The Cooperative Agreement[1] was finalized and signed by participating agencies in May 1987.

The Cooperative Agreement established the responsibilities of participating agencies, and provided a schedule and general work plan for accomplishing the Williston Basin Study. In general, the NDSDH's responsibilities included preparation of an emissions inventory for the Study area, providing models and input data necessary for dispersion modeling, conducting dispersion modeling, investigating mitigating measures if exceedances of air quality values were predicted, and preparation of a technical report to discuss Study methodology and interpret model results (this report). The BLM's responsibilities included overall coordination of the project, selection of oil and gas fields to be included in the Study, providing a foreseeable-future development scenario for each selected field, and preparation of an Environmental Impact Statement if mandated by Study results. The BLM also provided auxiliary funding to the NDSDH to support accomplishment of its responsibilities.

The Montana State Department of Health and Environmental Sciences (MSDHES) was also included in the cooperative agreement, because well installations in Montana would potentially impact some oil and gas fields included in the Study. Therefore, the BLM provided funding to the MSDHES to prepare an emissions inventory for oil and gas wells in Montana which could potentially impact Study fields in North Dakota.

Though not included at the outset, the U.S. Forest Service also eventually became involved in the Study because of its responsibilities in the management of Federal lands in the Study area. The Forest Service's participation included the provision of additional financial support.

The Williston Basin Study began in 1988.

1.3 Report Organization

The balance of this report deals with methodologies and results for the Williston Basin Study. An overview of air quality management in North Dakota and its applicability to oil and gas production is provided in Section 2. A detailed description of the Study, including objectives and limitations, is provided in Section 3. Study methodologies, including procedures for emissions inventory preparation and dispersion modeling are discussed in depth in Section 4. Section 5 provides a discussion and interpretation of all modeling results. Study conclusions and a discussion of mitigating measures to address air quality value exceedances are found in Section 6. Finally, references cited are listed in Section 7 and acronyms/abbreviations are summarized in Section 8. Other pertinent information is provided in the Report Appendices including documentation of model input data for each Study field (Appendix B) and contour plots of dispersion model results for each Study field (Appendices C and D).

2. OVERVIEW OF STATE AIR QUALITY MANAGEMENT

Air quality in North Dakota is managed primarily through the Air Pollution Control Program of the NDSDH. The Program has regulatory authority for protection of the air resource, which includes permitting or registration of pollution sources, and maintenance of all ambient air quality standards and PSD increments. Applicability of State air quality regulations to oil and gas processing facilities, and the Williston Basin Study, is discussed here.

2.1 General Regulations

The foundation for the State Air Pollution Control Program was established by the Federal Clean Air Acts of 1963-67. Although these Acts set the wheels in motion for protecting air quality through local programs, by 1970, Congress recognized that air pollution is a national problem requiring a national solution and passed the Clean Air Act Amendments of 1970. These amendments authorized the setting of uniform National Ambient Air Quality Standards and established a general strategy for air pollution control. In addition, the amendments established timetables for action. Although these amendments strengthened the Federal government's role in air pollution control, the law reaffirmed that State and local governments have the primary responsibility to limit air pollution.

On December 5, 1974, the U.S. Environmental Protection Agency (EPA) promulgated the original Prevention of Significant Deterioration (PSD) regulations which have been amended several times since. The intent of the PSD program was to limit the degree of further air quality degradation which could occur in areas already in compliance with ambient air quality standards. Federal PSD regulations provided for the categorization of those areas in the country in compliance with Federal Ambient Air Quality Standards as Class I, Class II, or Class III. The Class I designation identifies areas where further air quality degradation is least desired (National Parks, Wilderness Areas, etc.), and Class III identifies areas where further degradation is of least concern. PSD increments, which define the maximum allowable air quality degradation with respect to certain pollutants, were established for each category. To date, increments have been established for sulfur dioxide, total suspended particulate, and nitrogen dioxide.

In addition to the increments, the PSD regulations provided for the protection of visibility in Class I areas and the use of Best Available Control Technology (BACT) for controlling emissions from major stationary sources and major modifications.

The North Dakota State Department of Health initiated the development of the State air pollution control program in the 1960's. The State Legislature passed the North Dakota Air Pollution Control Law in 1969, a State Implementation Plan (SIP) was developed, and rules (regulations) were adopted[2]. During the rule-making process, it was acknowledged that North Dakota has some of the cleanest air in the country and that some special industries may cause a deterioration of air quality. Recognizing these facts, State Ambient Air Quality Standards were developed which were somewhat more comprehensive than the Federal Standards. The standards that were adopted included a sulfur dioxide standard that was based on a 1-hour averaging period and hydrogen sulfide standards. The Federal Ambient Air Quality Standards did not include these standards.

The State 1-hour sulfur dioxide (SO_2) standard was established at 715 $\mu g/m^3$ (0.273 ppm) which is more restrictive than the Federal 3-hour standard of 1300 $\mu g/m^3$ (0.50 ppm). The 24-hour SO_2 standard was set at 260 $\mu g/m^3$ (0.099 ppm) which is less than the Federal ambient standard of 365 $\mu g/m^3$ (0.14 ppm). The annual SO_2 standard was set at 60 $\mu g/m^3$ (0.023 ppm), which is also more restrictive than the Federal Standard of 80 $\mu g/m^3$ (0.03 ppm). These standards have not changed since they were originally promulgated.

State hydrogen sulfide standards were promulgated primarily to control emissions from the oil production industry. The standards were initially established at 45 $\mu g/m^3$ (0.032 ppm) maximum half-hour concentration not to be exceeded more than twice in any five consecutive days and 75 $\mu g/m^3$ (0.054 ppm) maximum half-hour concentration not to be exceeded more than twice per year. In 1987, these standards were replaced with one standard set at 70 $\mu g/m^3$ (0.05 ppm) maximum 1-hour concentration not to be exceeded more than once per year. These standards were set primarily to control the odors caused by hydrogen sulfide and were not health-based or welfare-based (property damage) standards.

North Dakota and Federal Ambient Air Quality Standards are summarized in Table 2-1.

TABLE 2-1
Ambient Air Quality Standards
($\mu g/m^3$)

Pollutant	Averaging Period	North Dakota	Federal
Sulfur Dioxide	1-hour	715	—
	3-hour	—	1300 *
	24-hour	260	365 *
	Annual	60	80
Hydrogen Sulfide	1-hour	70 *	—
Nitrogen Dioxide	1-hour	200 **	—
	Annual	100	100
Particulate (PM-10)	24-hour	150 *	150 *
	Annual	50	50
Ozone	1-hour	235 *	235 *
Lead	Quarterly	1.5	1.5
Carbon Monoxide	1-hour	40,000 *	40,000 *
	8-hour	10,000 *	10,000 *

*One exceedance per year is permitted.
**Not to be exceeded more than 1 percent of the time in any calendar quarter.

The NDSDH began developing its PSD regulations in 1975. The regulations became effective in February of 1976 and the U.S. EPA granted delegation of the PSD program to the NDSDH on May 26, 1977. Under the program, the three units of the Theodore Roosevelt National Park (TRNP North Unit, South Unit, Elkhorn Ranch Unit) and the Lostwood National Wilderness Area (NWA) are mandatory Class I areas. The rest of North Dakota is categorized as Class II. PSD Class I areas in North Dakota are shown in Figure 2-1.

The PSD rules are found in Chapter 33-15-15 of the North Dakota Air Pollution Control Rules and are similar to the Federal regulations with the major differences being the annual increment for sulfur dioxide in Class II areas and the redesignation (reclassification) procedures. The Class II annual increment for sulfur dioxide was established in the North Dakota PSD rules at 15 $\mu g/m^3$, which is more restrictive than the Federal increment of 20 $\mu g/m^3$. North Dakota PSD increments are summarized in Table 2-2.

TABLE 2-2
PSD Increments - North Dakota
($\mu g/m^3$)

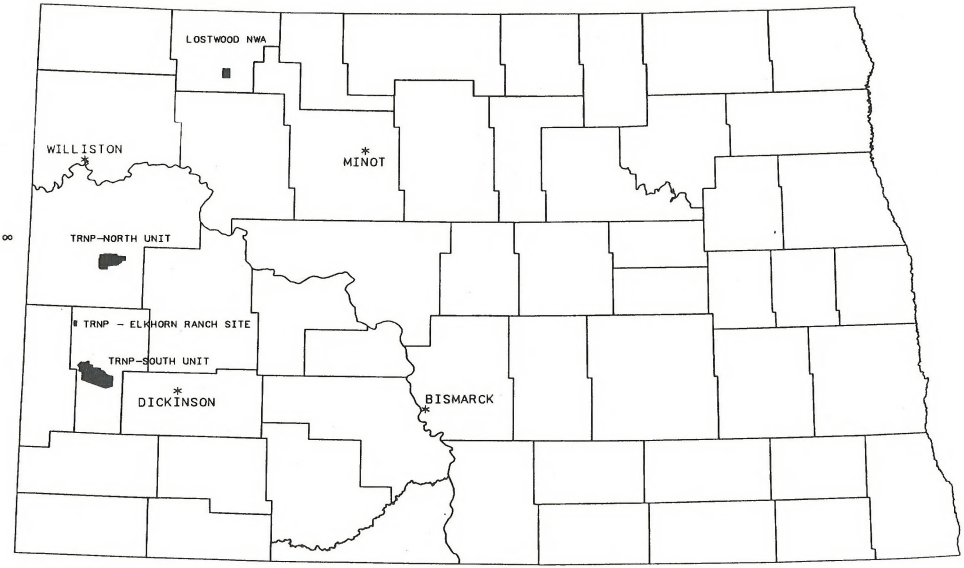
Pollutant	Class I	Class II	Class III
Sulfur Dioxide:			
Annual arithmetic mean	2	15 **	40
24-hour maximum*	5	91	182
3-hour maximum*	25	512	700
Particulate Matter (TSP):			
Annual geometric mean	5	19	37
24-hour maximum*	10	37	75
Nitrogen Dioxide:***			
Annual arithmetic mean	2.5	25	50

*3-hour and 24-hour increments can be exceeded one time per year.
**The annual average Class II value for SO_2 is the only State increment that differs from corresponding Federal increments. The Federal value is 20 $\mu g/m^3$.
***Currently undergoing promulgation procedures.

Pollution sources are subject to the PSD provisions only if they come into existence after a cutoff "baseline" date, and are considered "major" or reflect a "major modification" as defined in the Chapter 33-15-15 rules. An oil and gas well, for example, would have to potentially emit 250 tons or more of SO_2 per year (from flaring and/or treater operation) to be considered major, and thus subject to all PSD rules. In such case, the well would be called a "PSD" well.

It should be recognized that all pollution sources which came into existence after the baseline date consume PSD increment, even if they are not large enough to be considered major. Thus, an important distinction must be made between sources which are "PSD" and sources which are "PSD-increment-

Figure 2-1. PSD Class I Areas



consuming". All sources which came into existence after the baseline date are "PSD-increment-consuming". However, only those sources which can be defined as major are "PSD", and thus subject to all PSD rules including BACT compliance and assessing Class I visibility impact. Sources which are not major are "PSD-increment-consuming" but are not "PSD", i.e., they consume PSD increment but are not subject to other provisions of the PSD rules (e.g., BACT). Whether a source is major or not, however, it can be held accountable if it contributes to predicted exceedances of PSD increment.

2.2 Regulations Specific to Oil and Gas Facilities

By 1987, the oil production industry had grown enormously since the initial adoption of the North Dakota Ambient Air Quality Standards. In order to assure compliance with these standards and other Federal regulations such as the Prevention of Significant Deterioration (PSD) rules, the NDSDH adopted rules specific to the oil and gas production industry. These rules are found in Chapter 33-15-20, "Control of Emissions from Oil and Gas Production Facilities," of the North Dakota Air Pollution Control Rules. These rules establish a registration system for oil and gas wells and outline specific requirements for the control of emissions from oil and gas production facilities.

The rules require the owner or operator of a well completed or recompleted after July 1, 1987, or any well existing prior to this date that would emit 10 tons per year or more of any sulfur compound to register the well with the NDSDH. A registration form containing information concerning the oil and gas production rate of the well, production equipment located at the well site, an analysis of the gas, and a list of air pollution control equipment at the site must be submitted. Though not specifically a permitting process, the NDSDH can ascertain from the registration information whether the oil production facility should comply with the North Dakota Air Pollution Control Rules, including applicable ambient air quality standards and PSD increments. To date, approximately 700 wells have been registered with the NDSDH.

Chapter 33-15-20 also requires owners/operators of oil and gas production facilities to flare waste gas that contains hydrogen sulfide or treat it in an equally effective manner prior to releasing it to the atmosphere. If a flare system is used, the flare must be equipped with an automatic ignitor or a continuous burning pilot.

The hydrogen sulfide ambient air quality standards and a portion of Chapter 33-15-20 of the North Dakota Air Pollution Control Rules are currently undergoing review for possible changes.

2.3 Air Quality Assessment

To assess the impact or potential impact of pollution sources on ambient air quality standards or PSD increments, the NDSDH utilizes air quality monitoring and air quality modeling. Air quality monitoring stations are deployed by the NDSDH in various locations of the State. Some of these stations were implemented to accommodate minimum EPA monitoring requirements. Monitored pollutants include particulate matter (PM-10), sulfur dioxide, nitric oxide, nitrogen dioxide, hydrogen sulfide, and ozone. While the NDSDH monitoring sites provide an overall regional indication of air quality, they are not generally sited to address the maximum impact from individual sources.

In support of permitting requirements, several industry-operated monitoring stations are also located in the State. Such stations are usually located so as to detect the maximum air quality impact associated with a specific source. Thus, these monitoring sites are used by the NDSDH to determine the status of certain

sources with respect to ambient air quality standards. Air quality monitors cannot generally be used to assess PSD increments because of the possibility that sources which do not consume PSD increment may be contributing to the observed pollutant concentration.

While air quality monitors can provide a very reliable assessment of air quality in specific locations, it would not be economically feasible to locate a sufficient number of monitoring stations to address the maximum air quality impact of all significant pollution sources in the State. Moreover, monitors cannot be used to assess potential air quality impact associated with new source permitting, and cannot generally be used to assess PSD increment consumption. Thus, the NDSDH uses EPA-approved dispersion models to assess the air quality impact (ambient air quality standards and PSD increments) of potential new sources, and of existing sources when monitoring is not feasible.

Air quality models are complex mathematical algorithms and are usually computer-based. Model predictions are based on the input of certain source parameters and representative meteorological data. The accuracy of predicted pollutant concentrations is dependent on the quality of the input data, and of the algorithm itself.

While dispersion models have inherent limitations related to accuracy, they allow detailed analysis of air quality problems on a reasonably economical basis. Thus, dispersion modeling was concluded to be applicable to the Williston Basin air quality problem, which involved numerous sources and a large study area.

3. DESCRIPTION OF STUDY

This section of the report provides an overview of the project, including a description of the Study area, a presentation of Study objectives, and a discussion of Study limitations which could have a bearing on interpretation of results.

3.1 Description of Study Area

The Study involves oil and gas production facilities in the western part of North Dakota, in the region known as the Williston Basin. The Williston Basin is actually a geological feature (intracratonic basin) which covers western and central North Dakota, and also extends into South Dakota, Montana, and Canada. The Williston Basin Study involves the subregion located in western North Dakota, which is characterized by prolific oil and gas development. Counties included in the Study area are Golden Valley, Billings, Stark, Dunn, McKenzie, Williams, Mountrail, Ward, Burke, and Renville. The general Study area is depicted in Figure 3-1.

3.1.1 Land Use

Land use in the Study area is oriented predominantly to agricultural activities. Because a significant portion remains as Federal or public lands, however, the area also serves recreational interests and as a habitat for wildlife grazing. Cash-crop farming is dominant in the northern part of the area, where terrain relief is relatively gradual and conducive to tillage. In the southern part of the Study area, terrain relief is more severe, and land use is directed primarily toward ranching and wildlife habitat. The North Dakota Badlands and Theodore Roosevelt National Park (South Unit, North Unit, Elkhorn Ranch Unit) are located in the southern part of the Study area and serve as recreational areas and wildlife habitat. Lake Sakakawea, located approximately in the center of the Study area, also provides recreational opportunities.

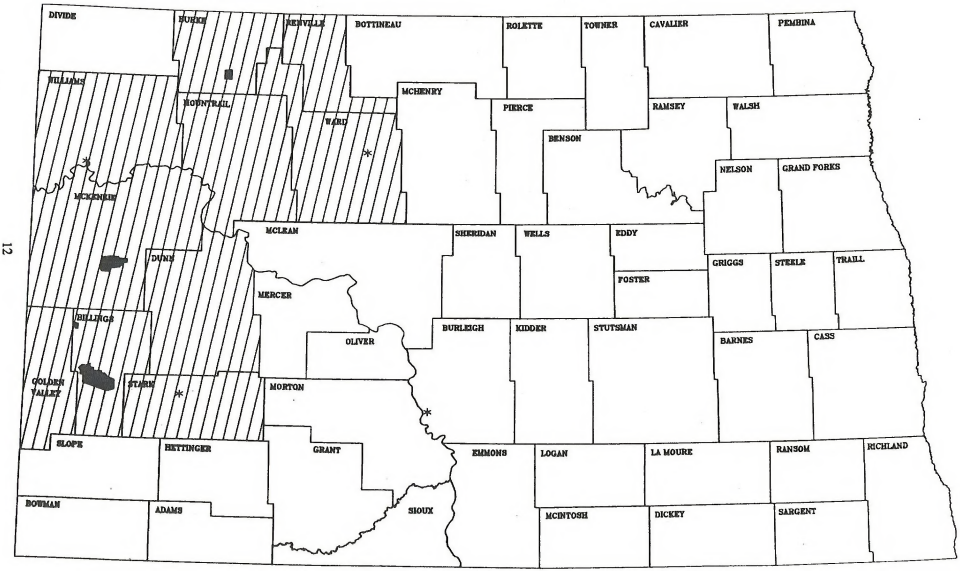
Though not constituting a very large percentage of total land area, energy development is a critical component of land usage in the Study area. Oil and gas wells and associated production facilities are scattered throughout the area, and one surface coal mine operates in the area. The potential exists for significant additional energy development. Activity associated with energy development has a significant impact on the economy and environment of the area.

3.1.2 Climate

Climate in the Williston Basin Study area can be classified as semiarid, with substantial annual and longer-term variability in temperature and precipitation. Rapidly moving air masses during much of the year create very changeable and unreliable weather patterns. Climate does not significantly vary across the Study area.

Monthly average temperatures for the Williston, North Dakota National Weather Service station are shown in Table 3-1. The Williston observations are representative of climate throughout the Study area. As shown in Table 3-1, the difference between the average July temperature and average January

Figure 3-1. Williston Basin Study Area



temperature is more than 60°F, reflecting a large annual variation. Long-term temperature extremes (1951-1980) in the area range from near -50 °F in winter to near 115°F in the summer.

TABLE 3-1
Monthly Average Temperature (°F)*
Williston

January	6.6
February	14.6
March	25.3
April	41.8
May	54.5
June	70.0
July	70.0
August	68.1
September	56.6
October	45.1
November	27.6
December	14.9

*Based on the period 1951 - 1980

Table 3-2 presents monthly normal precipitation for Williston. As indicated in Table 3-2, precipitation is generally low and occurs mainly in the summer and early spring. It is only during the warmer summer months that the dew point rises high enough to create the potential for significant precipitation. To compound the negative impact of low annual precipitation on agriculture and other concerns, the year-to-year deviation from normal precipitation tends to be significant. Thus, the area is subject to cycles of drought and above-normal precipitation.

TABLE 3-2
Monthly Normal Precipitation (Inches)*
Williston

January	0.55
February	0.50
March	0.57
April	1.29
May	1.85
June	2.68
July	1.83
August	1.42
September	1.37
October	0.74
November	0.50
December	0.55
Total	13.85

*Based on the period 1951 - 1980.

Wind data from Williston are summarized in the wind rose of Figure 3-2. Winds from a northwesterly or southwesterly direction are most common in the area, but the frequency of southeast winds is also significant. Easterly or northeasterly winds are least common. Wind speeds are generally high, with strongest winds occurring in the winter and spring months when temperature gradients between adjoining air masses are most significant. The relatively high wind speed typical for the area is a positive factor for dispersion of air pollutants.

3.1.3 Monitored Air Quality

Within the Study area, the NDSDH operates SO_2 and H_2S monitoring sites at Theodore Roosevelt National Park (TRNP) South Unit, TRNP North Unit, and Lostwood National Wilderness Area (NWA). Until 1989, SO_2 and H_2S monitors were also located in the Lone Butte oil and gas field (east and south of the TRNP North Unit). NDSDH monitoring sites are shown in Figure 3-3.

Recent air quality monitoring data for SO_2 within the Study area are summarized in Table 3-3[3]. These monitoring data suggest that air quality in the Study area is generally very good. For 1985 through 1988, highest observed SO_2 concentrations at the TRNP South Unit, TRNP North Unit, and Lostwood NWA were well below applicable North Dakota Ambient Air Quality Standards (AAQS). Monitoring data for Lone Butte indicate exceedances of the 1-hour AAQS in 1986 and 1987, but a much lower maximum value in 1988. The lower observed concentrations in 1988 were due to mitigative actions, including the construction of an additional compressor which allowed the tie-in of additional wells to a centralized gas processing facility.

Before October 1, 1987, the State AAQS for H_2S were based on a half-hour averaging period, and monitoring data were accordingly reduced as half-hour averages. Thus, it would not be meaningful to compare the 1985 through 1987 observed H_2S values with the current AAQS (70 $\mu g/m^3$, 1-hour average). In 1988, highest observed 1-hour H_2S concentrations at the TRNP South Unit, TRNP North Unit, and Lostwood NWA were below the AAQS. At Lone Butte, however, the highest observed 1-hour H_2S concentration was 2121 $\mu g/m^3$, well above the AAQS.

These monitoring data, particularly for SO_2, suggest that air quality in the Study area is relatively good. This interpretation is not necessarily appropriate, however, because the NDSDH monitoring sites are located primarily based on concern for maintenance of air quality in areas where it is relatively pristine. With the exception of the Lone Butte site, monitors located within the Study area were not sited for the purpose of detecting maximum overall SO_2 and H_2S concentrations. Based on production volumes and various odor complaints, both the NDSDH and the BLM had reason to believe that monitors strategically placed with respect to certain oil and gas fields would have revealed much higher SO_2 and H_2S concentrations. Thus, the recent monitoring data were judged not to have a bearing on the need for the Williston Basin Study.

3.2 Description of Oil and Gas Processing Facilities

Numerous oil and gas fields are found in western and central North Dakota. The fields have been developed primarily for the production of crude oil, but northwestern and west-central North Dakota have also developed gas-gathering networks by which hydrocarbon vapors (natural gas), which are produced

Figure 3-2
Williston Wind Rose
1971 - 1983

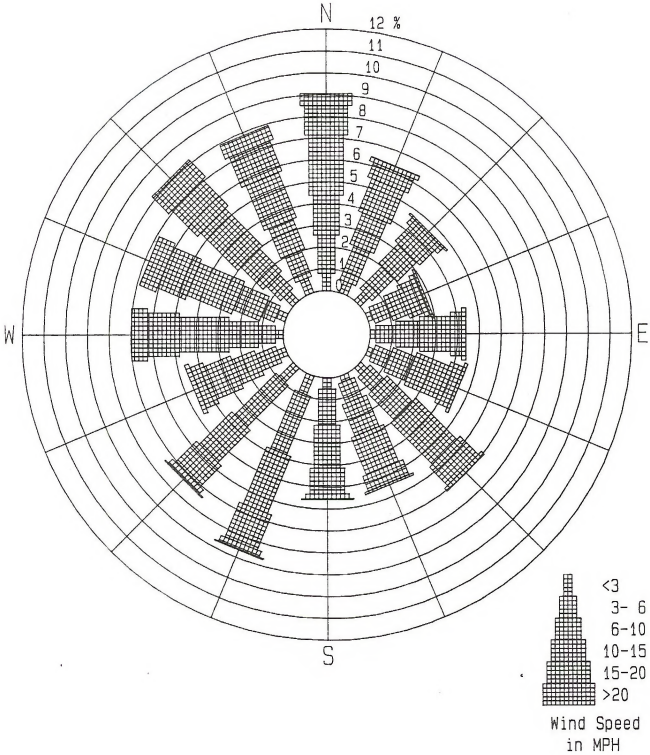


Figure 3-3. SO_2 and H_2S Monitoring Sites

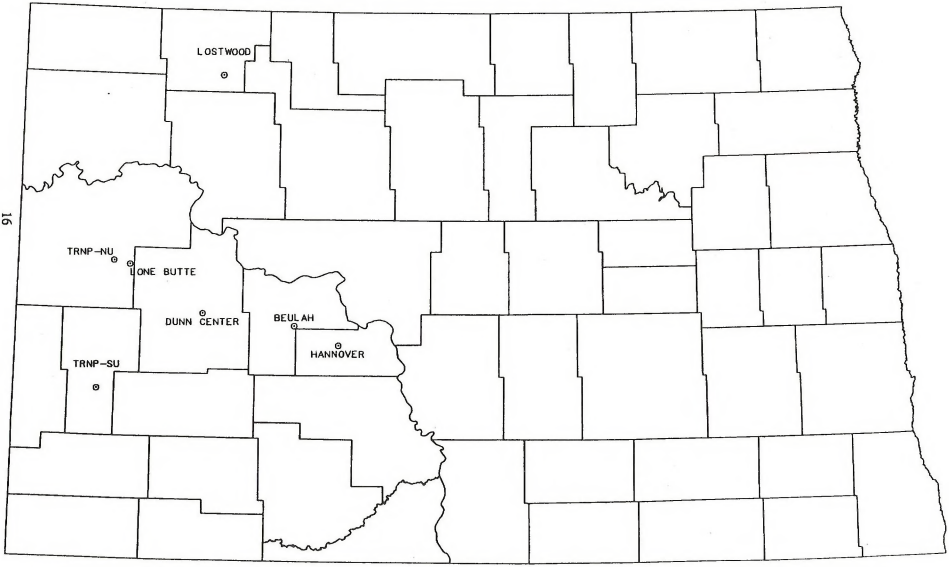


TABLE 3-3
NDSDH Air Quality Monitoring Data
Highest Observed SO_2 Concentrations

($\mu g/m^3$)

TRNP South Unit

Averaging Period	1985	1986	1987	1988	N.D. AAQS
1-hour	31	52	34	47	715
24-hour	8	15	15	17	260
Annual	3	3	3	3	60

TRNP North Unit

Averaging Period	1985	1986	1987	1988	N.D. AAQS
1-hour	107	183	81	110	715
24-hour	36	35	15	23	260
Annual	4	4	4	3	60

Lostwood NWA

Averaging Period	1985	1986	1987	1988	N.D. AAQS
1-hour	—	86	73	84	715
24-hour	—	21	12	34	260
Annual	—	3	3	4	60

Lone Butte

Averaging Period	1985	1986	1987	1988	N.D. AAQS
1-hour	713	734	815	327	715
24-hour	176	201	155	141	260
Annual	26	41	26	6	60

in association with crude oil, can be transported to gas processing plants. In areas not equipped with a gas-gathering pipeline system, the gas produced from a well is used to operate lease equipment and the excess is flared.

Surface equipment at a typical well site includes a separator and/or heater-treater, crude oil storage tanks, saltwater storage tanks, a circulating pump, and a flare. A typical well site is depicted in Figure 3-4. Reservoir fluids which flow or are pumped to the wellhead surface exist as an emulsion or mixture of oil, gas, and water. The produced fluid is transported through a flow line to a high-temperature/low-pressure heater-treater or to a low-pressure separator where the three constituents are segregated by gravity. The heater-treater contains a firing tube which heats the fluid to enhance the liberation of gas. The low pressure further enhances the liberation of dissolved gases. Separators can be run in series, or "staged", to accomplish a more refined product, but this is not common in North Dakota.

The saline water is transported from the treater by pipe to an on-site saltwater storage tank; from there it is transported by truck or pipeline to a North Dakota Industrial Commission approved saltwater disposal well for reinjection into a designated formation. The crude oil is piped to an on-site storage tank.

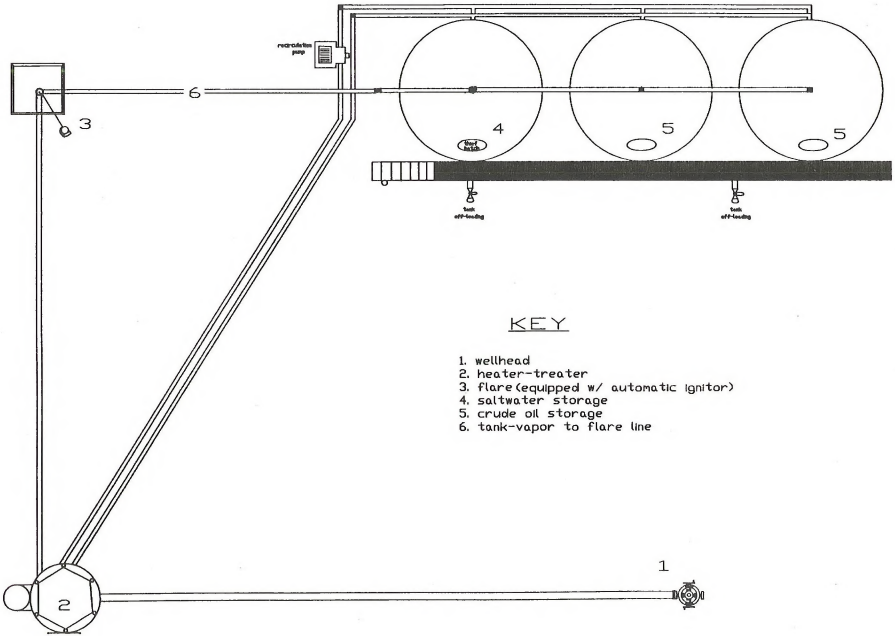
A portion of the gas coming off the treater is used as fuel to fire the treater. If the gas has a high concentration of hydrogen sulfide, it may be both corrosive to metals and dangerous. In such an instance, or if the produced gas volumes are too small to support treater requirements, propane or processed gas (if available) may be used as fuel to fire the treater. The balance of the gas coming off the treater is either routed to the flare or it is metered and routed to a gas sales line; this, of course, depends upon the availability of a gas-gathering (i.e., sales) line. For areas remote to gas processing plants, gas-gathering networks have not been developed, and thus, gas sales are not feasible.

Depending on the efficiency of the treater/separator system, a certain amount of gas will continue to come out of solution in both the salt water and crude oil storage tanks. If these tank vapors are of significant volume or contain a significant amount of hydrogen sulfide, the tanks are connected to a manifold which is tied in to the flare.

In some instances, petroleum from individual wells is transported by flow lines to a centralized tank battery prior to undergoing the processes described above. This scenario is characteristic of unitized oil fields, where pooling of royalty interests has taken place under the authorization of the Industrial Commission. It may also be economically advantageous to co-locate the surface equipment for wells which have a common operator and common subsurface mineral ownership. The production from each individual well may be commingled and processed through common equipment or it may remain segregated and a set of processing equipment for each well may be maintained at that central processing site.

Well installations can release significant amounts of sulfur dioxide and hydrogen sulfide into the atmosphere. Sulfur dioxide emissions are the result of the combustion of hydrogen sulfide-contaminated gas in treaters and flares. Emissions of hydrogen sulfide result from the fugitive release of raw gas from leaky valves, pipe connections or tank hatches, or from the incomplete combustion of gas at the treater or flare.

Figure 3-4. Schematic of Typical Well Site Facilities



3.3 Study Objectives

The first objective of the Williston Basin Study was to determine the existing and foreseeable-future air quality impact of oil and gas production for selected oil and gas fields in western North Dakota. The second objective involved the investigation of mitigative actions to correct air quality problems related to oil and gas production if such problems were shown to exist. It was concluded that fulfillment of these objectives would foster the ultimate management goal of ensuring adequate protection of air quality, while still allowing reasonable continued oil and gas development in the area.

As indicated in Section 3.2, oil and gas production facilities have the potential to emit significant amounts of the pollutants sulfur dioxide (SO_2) and hydrogen sulfide (H_2S). Thus, the Study included an assessment of both SO_2 and H_2S emissions on air quality for selected oil and gas fields. Emissions inventories of SO_2 and H_2S sources in the Study area were prepared, and computer dispersion models subsequently applied to predict existing ambient levels of these pollutants, and to predict ambient levels for the foreseeable future.

Compliance status with respect to both ambient air quality standards (AAQS) and PSD increments was evaluated in the dispersion modeling analysis. As indicated in Section 2, SO_2 emissions are covered by PSD regulations as well as by AAQS. Thus, SO_2 emissions from PSD sources must comply with PSD increments as well as AAQS. H_2S emissions are not covered by PSD regulations, so H_2S emissions must comply only with the AAQS. The dispersion modeling analysis therefore included an assessment of air quality impact with respect to AAQS and PSD increments for SO_2, and with respect to AAQS for H_2S.

To facilitate analysis of existing and foreseeable-future SO_2 and H_2S emissions with respect to AAQS and PSD increments, the air quality modeling problem was grouped into seven scenarios which are outlined in Table 3-4. Essentially, a separate modeling procedure, with specific input data, was executed for each scenario. A future PSD Class I SO_2 scenario was not included because it was not called for in the Cooperative Agreement. It was concluded prohibitively cumbersome to develop a foreseeable-future emissions inventory for all of the many oil and gas fields whose wells would have to be addressed in order to model future impact on Class I areas. Preparation of input data and the air quality modeling procedure for each scenario are discussed in Sections 4.2-4.5.

Though numerous oil and gas fields are present in the Study area, it was concluded that air quality analysis would have to be limited to twelve fields because of resource constraints. Thus, twelve subject fields were selected based on representativeness and potential air quality impact. The field selection process is described in Section 4.1. Separate air quality analyses, incorporating the Table 3-4 scenarios, were applied for each subject field. The PSD Class I SO_2 scenario (Scenario 5), however, was not applicable to the twelve subject fields because they all lie in a PSD Class II area. The PSD Class I SO_2 scenario was applied instead for the four Class I areas located in the vicinity of the Study area.

In summary, to fulfill the Study objectives, the Williston Basin Study incorporated the following basic work plan:

1) Development of an emissions inventory (existing and foreseeable-future) for the entire Study area.

2) Selection of twelve oil and gas fields in western North Dakota as subjects for the Study.

TABLE 3-4
Williston Basin Study
Air Quality Modeling Scenarios

Scenario	Purpose
1 Existing Ambient SO_2	To determine existing status of air quality with respect to AAQS for SO_2
2 Future Ambient SO_2	To determine foreseeable-future status of air quality with respect to AAQS for SO_2
3 Existing PSD Class II SO_2	To determine existing status of air quality with respect to allowable Class II increments for SO_2
4 Future PSD Class II SO_2	To determine foreseeable-future status of air quality with respect to allowable Class II increments for SO_2
5 Existing PSD Class I SO_2*	To determine existing status of air quality with respect to allowable Class I increments for SO_2
6 Existing Ambient H_2S	To determine existing status of air quality with respect to the AAQS for H_2S
7 Future Ambient H_2S	To determine foreseeable-future status of air quality with respect to the AAQS for H_2S

*The Cooperative Agreement did not address foreseeable-future impact on PSD Class I increments.

3) Dispersion modeling for twelve subject oil and gas fields for the scenarios outlined in Table 3-4.

4) Dispersion modeling for four Class I areas with respect to the PSD Class I SO_2 scenario.

5) Assessment and interpretation of dispersion model results.

6) Investigation of mitigating measures to address exceedances of ambient air quality standards or PSD increments for fields where they were predicted.

7) Preparation of a technical report describing assumptions, methodologies, and results (this report).

Procedures for emissions inventory preparation, subject field selection, and dispersion modeling are described completely in Section 4. The investigation of mitigating measures is addressed in Section 6.

3.4 Study Limitations

Limitations associated with input data, or in the dispersion model itself, must generally be considered when interpreting air quality modeling results. Because the Williston Basin Study is primarily an air quality modeling exercise, it is thus appropriate to document its potential limitations. These limitations should be considered when reviewing Study results.

The limitations noted here are not intended to detract from the usefulness of the Williston Basin Study. The Study provides considerable information regarding potential air quality in oil and gas fields in western North Dakota, when little such information was previously available. The Study was conducted by individuals with considerable experience in air quality modeling analyses. Dispersion models utilized are state-of-the-art tools approved by the EPA. Though some subjectivity was involved in the preparation of model input data, assumptions and subjective decisions were based on deliberate input from knowledgeable individuals, including a NDSDH geological engineer and several representatives of the BLM. In short, a sincere and substantial effort was made to obtain the highest quality model predictions possible, given the resource constraints of the Study.

Potential limitations present in the Williston Basin Study are summarized below.

1) Development of SO_2 Emission Rates

SO_2 emission rates for treaters and flares were derived from production data and H_2S percentages contained in the State Industrial Commission's oil and gas data base. Entries in the data base are based on information provided by well operators. Thus, production data is only as accurate as the information provided by the well operator. Also, H_2S values were unavailable for many wells, and substitutions had to be made.

2) Treater and Flare Stack Parameters

For treaters and flares located within a subject Study field's boundaries, on-site measurements were taken to obtain accurate values for stack height and location. For treaters and flares located outside of the subject field, however, stack parameters were obtained from the Industrial Commission's oil and gas data base. Stack parameters were occasionally missing in the data base, and substitutions were necessary. Substitutions for missing treater and flare stack height were as specified in the Cooperative Agreement. Assumptions regarding stack parameters also had to be made for some commingled (serving more than one well) facilities.

3) Treatment of Foreseeable-Future Sources

Probable well locations for the foreseeable-future scenarios were provided by the BLM. However, it was concluded that not all future well locations should include active flares or SO_2-emitting treaters, because existing wells in some cases were tied-in to centralized gas processing plants (no flare) or used fuel other than sour gas for treaters (no SO_2 or H_2S emission). Thus, an arbitrary randomizing scheme was used to locate active flares and SO_2-emitting treaters among the future well locations. Also, emission rates and stack parameters for future treaters and flares were based on the average of existing values for treaters and flares associated with the same field and pool.

4) Uneven Terrain Not Considered

Because it would have meant significant additional project time and cost, the effects of uneven terrain were not considered in dispersion modeling analyses for Study fields (i.e., terrain assumed flat), even though modeling results could be significantly altered in some (limited) cases. Considerable time would have been required to assemble the necessary receptor elevations, given the extreme number of receptors involved.

The omission of terrain height variations from the modeling analyses, however, may not impact modeling results as much as initially conceived because treater and flare stacks tend to be short and plume rise is limited. With a taller stack (e.g., power generating station), the plume centerline draws significantly closer to the surface if a significant terrain feature (higher than plume height) lies in the path of the plume, particularly in very stable conditions. In this case, the distance between the plume centerline and the surface may be much closer near the terrain feature than it is in the immediate vicinity of the stack. Thus, the assumption of flat terrain could lead to erroneously low predictions.

But atmospheric boundary-layer dynamics impose a constraint on the action of a plume approaching a terrain feature, such that the plume is forced to bend over or around the feature, even in very stable conditions. The plume centerline is constrained to approach no closer than a certain distance to the feature, even under circumstances of "terrain impaction". This distance is generally regarded by the EPA to be ten meters. Given this constraint, and the typically small size of treater and flare stacks, the distance between their plume centerline and the surface may not be significantly different near the terrain feature than it is near the stack. Thus, the assumption of flat terrain may not necessarily lead to erroneously low predictions.

5) Representativeness of Meteorological Data

As discussed in Section 4.3.5, Williston meteorological data were used for modeling analyses for all twelve Study fields. Given the likelihood of local channeling effects caused by terrain height variations in some Study fields, and the distance of some fields from Williston, the Williston data set is probably not completely representative for all Study fields. The use of a single set of meteorological data was desirable, however, to allow consistent treatment and subsequent consistent interpretation of results for all twelve subject fields.

6) H_2S Concentration Estimates

As explained in Section 4.5, H_2S concentration estimates were based on a conversion of SO_2 results. A constant H_2S-to-SO_2 conversion efficiency (through combustion-oxidation) of 75 percent was assumed for both treaters and flares. Though this value was derived from a consensus opinion of NDSDH and BLM representatives, it is very arbitrary given the wide range of values documented in literature. (Conversion efficiency was assumed at 100% for SO_2 analyses.)

The above comments on potential limitations in the Williston Basin Study may become more meaningful upon review of the procedures described in Section 4.

4. PROCEDURE

The procedure used in the Williston Basin Study followed the basic work plan outlined in Section 3.3. Twelve oil and gas fields were selected as subjects for the Study, and an emissions inventory was developed for the entire Study area. Dispersion modeling was performed to determine the impact of subject-field SO_2 and H_2S emissions on air quality for each of the Study scenarios (Section 3.3). Finally, dispersion modeling results were summarized and interpreted using tabular and graphical methods.

4.1 Selection of Subject Oil and Gas Fields

As specified in the Cooperative Agreement, a total of twelve North Dakota oil and gas fields were selected for inclusion in the Williston Basin Study. To accommodate the field-selection process, the NDSDH prepared objective rankings of field suitability using oil and gas production data obtained from the North Dakota State Industrial Commission. The State Industrial Commission maintains a computer data base of monthly production data which are derived from mandatory reports filed by well operators. The data base includes such parameters as gas production volume sold, gas production volume used on the lease site, gas production volume vented or flared, monthly days of production, and gas H_2S percent for each well in the State.

The NDSDH generated three listings ranking fields on the basis of:

1) total field SO_2 emissions,

2) average SO_2 emissions per well installation, and

3) average H_2S content (ranked on a field-pool basis).

Total field SO_2 emissions were derived from gas production data by conservatively assuming that all lease-use gas is associated with treater operation, all vent-flare gas is associated with flare operation, and that treater and flare operation result in 100 percent conversion of H_2S to SO_2 (these assumptions and SO_2 emission calculations are discussed in greater detail in Section 4.2). The NDSDH submitted the three listings, along with initial comments regarding field preference, to the BLM[4]. The field-ranking lists are included in Appendix A of this report.

Using the information provided by the NDSDH, the BLM made the final selection of the twelve Study fields[5]. The BLM indicated their decision was based on:

1) the field-ranking lists provided by the NDSDH,

2) an assessment of field development potential, and

3) a desire to model air quality impacts across a broad geographical area.

The twelve oil and gas fields selected for the Williston Basin Study are listed in Table 4-1. Locations of the twelve fields are depicted in Figure 4-1.

TABLE 4-1
Oil and Gas Fields Selected for Williston Basin Study

Big Stick	Lost Bridge
Buffalo Wallow	Rough Rider
Charlson	Scairt Woman
Elkhorn Ranch	Smith
Little Knife	Stanley
Lone Butte	Whiskey Joe

4.2 Preparation of Emissions Inventories

Preparation of the Emissions Inventory comprised the most challenging aspect of the Williston Basin Study. Because dispersion modeling analyses had not been previously conducted for a majority of oil and gas wells in the Williston Basin, model input parameters were not available and had to be extracted or derived from the State Industrial Commission's oil and gas data base. Further, development of the foreseeable-future inventory required that well locations and configurations had to be projected.

4.2.1 Emissions Inventory Parameters

The emissions inventories were constructed primarily to accommodate the source data (input) requirements of the dispersion models utilized in the Williston Basin Study. As described in Sections 4.3 and 4.4, the EPA Industrial Source Complex Short-Term (ISCST) model[16] and the State's MSPUFF model[23] were selected for use in the Study. Source data requirements are the same for both models. Required input parameters are shown in Table 4-2.

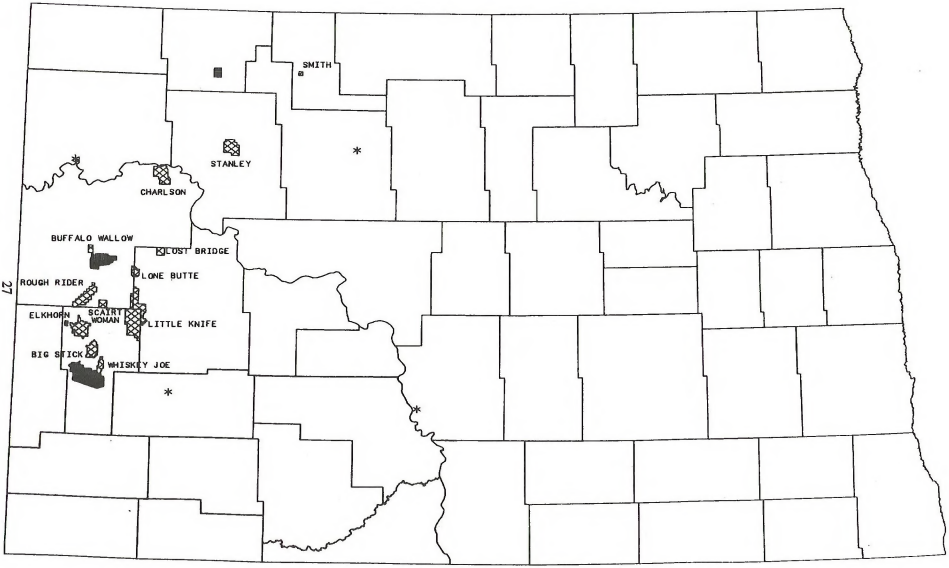
TABLE 4-2
Required Source Input Data for Dispersion Models*

Parameter	Units
Stack Location (X)	meters
Stack Location (Y)	meters
Pollutant Emission Rate	g/sec
Stack-base Elevation	meters
Stack Height	meters
Stack Diameter	meters
Stack Gas Exit Velocity	meters/sec
Stack Gas Exit Temperature	°K

*One set of data is required for each source included in the analysis.

The Williston Basin Study involved projection of air quality with respect to both SO_2 and H_2S. However, dispersion models were used only for SO_2 predictions. H_2S concentration estimates were obtained through

Figure 4-1. Locations of Study Fields



a straight conversion of model results for SO_2 (see Section 4.5). Thus, the emissions inventory included emission rates for SO_2, only.

SO_2 emissions from oil and gas well installations, as noted in Section 3.2, result from the operation of treaters and flares. Thus, it was determined that the emissions inventory should include the Table 4-2 parameters for each treater and flare in the Study area, and for all projected treaters and flares associated with the foreseeable-future scenario. For flexibility, separate emissions inventories were maintained for existing and future (foreseeable-future) scenarios (the future scenario inventory included data for future well sites, only).

The State Industrial Commission's (SIC) oil and gas data base is the only readily available source of well data from which model input parameters for treaters and flares can be derived (note that data collected via the NDSDH well registration system is entered into the SIC data base). Thus, the existing emissions inventory was constructed using data exclusively from the SIC oil and gas data base. The future emissions inventory was prepared through extrapolation of corresponding values in the existing inventory, along with additional input from the BLM.

The State Industrial Commission's oil and gas data base includes explicit parameters for flare location, treater location, flare stack height, and treater stack height for each well. The data base does not explicitly provide the other required parameters listed in Table 4-2, i.e., treater/flare emission rate, stack-base elevation, stack diameter, exit velocity, or exit temperature. However, treater and flare SO_2 emission rates can be calculated from H_2S percentages and production data included in the data base. Treater/flare stack diameter, stack exit temperature, and stack exit velocity can be derived from the heat of combustion which, in turn, can be calculated from data-base production data as explained in Section 4.2. Stack-base elevation was not required because flat terrain was assumed for the Williston Basin Study.

Based on the above determinations, it was concluded that the emissions inventories should include values for, at a minimum, treater/flare location, SO_2 emission rate, stack height, and heat of combustion. Therefore, mandatory parameters for inclusion in both existing and foreseeable-future emissions inventories are those shown in Table 4-3.

TABLE 4-3
Mandatory Parameters for WBS Emissions Inventories*

Well Identification Number
Field Name
Well PSD Status
Treater Location (X)
Treater Location (Y)
Treater Stack Height
Treater SO_2 Emission Rate
Treater Heat of Combustion
Flare Location (X)
Flare Location (Y)
Flare Stack Height
Flare SO_2 Emission Rate
Flare Heat of Combustion

*One set of parameters required for each well.

4.2.2 Inventory for Existing Scenarios

The existing scenario inventory is comprised of data for all North Dakota wells and some Montana wells. Though the Williston Basin Study area constitutes only a subregion of the oil and gas producing region in North Dakota, it was concluded that inclusion of all wells may be useful for future studies (it was the BLM's original intention to model additional oil and gas fields after completion of the Williston Basin Study). All Study fields were located in North Dakota; however, emissions data were needed for some Montana wells because of their proximity to, and resultant potential additive air quality impact on, some of the Study fields.

All existing inventory data for North Dakota wells were obtained explicitly, or derived indirectly, from the State Industrial Commission's oil and gas computer data base. The oil and gas data base is assembled from monthly production reports filed by well operators. The data base includes a relatively static file which includes generally constant background information for each well in the State, and a more dynamic file which includes monthly production information for each well and is updated (appended) on an ongoing basis.

Of the required emissions inventory parameters given in Table 4-3, treater/flare location, treater/flare stack height, well PSD status (based on completion date), and a well identification number (permit number) were obtained from the oil and gas data base static file. Treater/flare SO_2 emission rate and heat of combustion were derived from H_2S percentages in the static file and monthly production information contained in the dynamic file. Monthly production data for gas in the dynamic file is partitioned into sales volume, lease-use volume, and vent-flare (combined) volume. For the Williston Basin Study, it was assumed that the lease-use volume is attributed entirely to treater operation and the vent-flare volume is attributed entirely to flaring. These are reasonable assumptions because venting of gas, and lease-use of gas, apart from treater fuel, are typically very minimal at well installations in North Dakota.

Because production data in the oil and gas data base are stored on a chronological monthly basis, it was necessary to define an interval over which monthly production figures would be averaged for derivation of treater/flare SO_2 emission rate and heat of combustion. The NDSDH suggested that treater operation, and resultant air quality impact, would probably be at a maximum during winter months. Upon consultation with the BLM, therefore, it was decided to base average SO_2 emission rate and heat of combustion on the five-month period November 1987 through March 1988[6] (the most recent winter months for which production data were available at the time).

Information in the State Industrial Commission's oil and gas data base is provided on the basis of individual wells. Nothing can be inferred from the data base regarding possible commingling of well production at a centralized processing facility. Thus, centralized processing facilities were not considered by the NDSDH in creating the emissions inventory. The inventory includes one entry for each well. It should be noted, however, that on-site inspections were incorporated in the process of preparing model input data for the twelve Study fields (Section 4.3.3). These inspections allowed model input to appropriately reflect centralized processing facilities located within Study fields.

Existing inventory data for Montana was provided by the Montana State Department of Health and Environmental Sciences (MSDHES). The MSDHES was assigned this responsibility as a result of its participation in the Cooperative Agreement. The MSDHES provided well data in a format requested by the NDSDH[7]. Included in the MSDHES submittal was a well identification number, well name, location, active pool name, H_2S percent, SO_2 emission rate, and heat of combustion for about 550 wells in the vicinity of the North Dakota-Montana border.

Extensive computer software systems were developed to extract or derive the necessary parameters for construction of the existing emissions inventories. Because of the difference in data sources, separate software systems were developed to create the inventories for North Dakota and Montana wells. The two resulting inventories were subsequently merged to form a single, final emissions inventory for the existing scenario. The software system used to create the North Dakota existing inventory is illustrated in Figure 4-2, and the software system used to create the Montana existing inventory is summarized in Figure 4-3. A description of the specific procedures used to develop the existing emissions inventory, and the associated components shown in Figures 4-2 and 4-3, follows in Sections 4.2.2.1 - 4.2.2.4.

4.2.2.1 Extraction of Data From SIC Oil and Gas Data Base

The first step in preparing the inventory for North Dakota wells was to extract necessary data from the State Industrial Commission's oil and gas data base. A large number of parameters are stored in the oil and gas data base static and dynamic files, most of them unnecessary for the emissions inventory. To prepare the existing well inventory as outlined in Table 4-3, it was thus concluded that the data base parameters outlined in Table 4-4 should be exported to a smaller work file for more convenient processing.

TABLE 4-4
Work File Parameters
Exported from Oil and Gas Data Base*

Field Name
File Number (Well ID Number)
Well Name
Well Number (unique within field)
Well Location (legal)
Well Footage
Treater Location (legal)
Treater Footage
Treater Stack Height
Flare Location (legal)
Flare Footage
Flare Stack Height
Number of Pools (1-4)
Pool Name (each pool)
Completion Date (each pool)
H_2S Percent (each pool)
H_2S Method (each pool)
Monthly Days of Production (each pool, Nov '87-Mar '88)
Monthly Wellhead Gas Production (each pool, Nov '87-Mar '88)
Monthly Lease-Use Gas Production (each pool, Nov '87-Mar '88)
Monthly Vent-Flare Gas Production (each pool, Nov '87-Mar '88)

*One set exported for each well.

FIGURE 4-2

EMISSIONS INVENTORY

CREATION SYSTEM:

NORTH DAKOTA WELLS

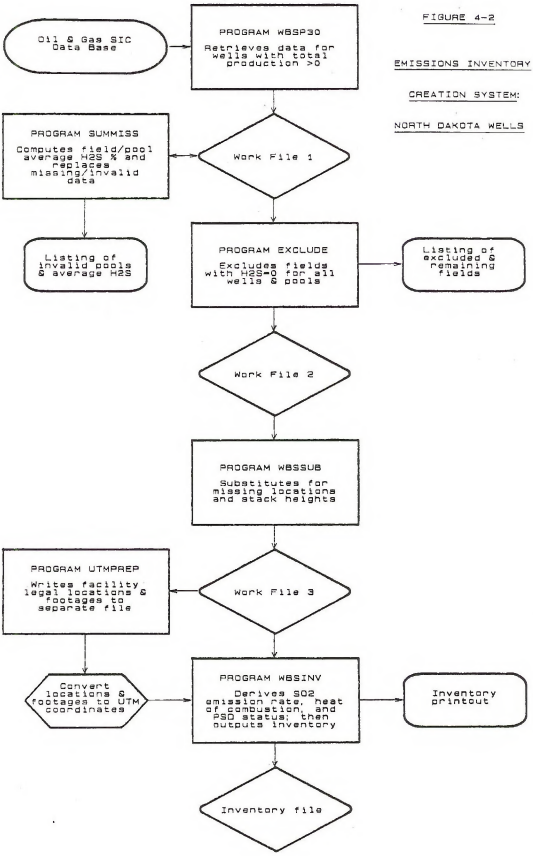
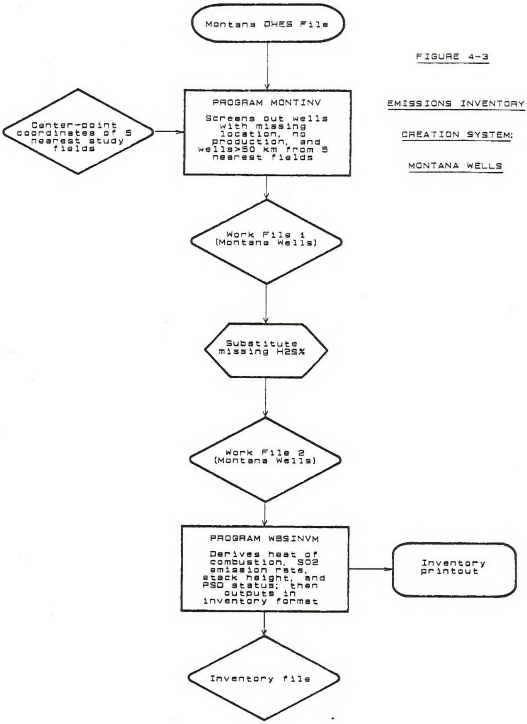


FIGURE 4-3

EMISSIONS INVENTORY

CREATION SYSTEM:

MONTANA WELLS



This step was accomplished with the preparation and execution of Natural (data-base retrieval programming language) program WBSP30, as illustrated in the flow chart of Figure 4-2. Output from the export procedure was labeled "Work File 1" to distinguish it as the first iteration in a series of operations leading to the final inventory. During the export process, data were screened by program WBSP30 so that only wells with total gas production (wellhead) greater than zero, for the period November 1987 through March 1988, were passed along to the work file.

All of the Table 4-3 elements can be reduced or derived from the work file parameters. Treater/flare stack height is explicitly available. As detailed in Section 4.2.2.3, treater/flare location in cartesian coordinates is derived from treater/flare location (legal) and footage. SO_2 emission rate for treater/flare is derived from H_2S percent, monthly days of production, and monthly lease-use/vent-flare gas production. Treater/flare heat of combustion is derived from monthly days of production and monthly lease-use/vent-flare gas production. Well PSD status is derived from completion date. Other work file parameters were needed when substitutions for missing data were determined necessary, as explained in Section 4.2.2.2.

4.2.2.2 Handling Missing Data

Not unexpectedly, some entries for treater/flare location, treater/flare footage, treater/flare stack height, and H_2S percentage were missing in the oil and gas data base. Therefore, the next step in the creation of the emissions inventory for existing wells was to substitute for missing data in the work file.

Even if it was not actually missing from the data base, H_2S percent was treated as missing if it was not associated with a valid H_2S testing method (recall from Table 4-4 that "H_2S method" is available in the oil and gas data base and was exported to the work file). The NDSDH regards Tutweiler, Draeger Tube, and Chromatography (abbreviated as TUT, DRA, and LAB, respectively, in the data base) as the only valid H_2S methods because they are the only methods which involve a well-specific, documented test. Chromatography involves laboratory analysis of a gas sample collected on-site, while Tutweiler and Draeger Tube methods normally involve on-site gas analysis.

Upon considering appropriate substitution schemes for missing or invalid H_2S percentage, the NDSDH concluded that the following should be used, in order of priority.

1) The average of all valid entries from the same field and pool is substituted.

2) If no valid entries are present for the pool in the same field, the average of all valid entries for the same pool from a nearby field is substituted.

3) If no valid entries are present for the same pool in any nearby field, the average of all valid entries for a geologically similar pool from a nearby field is substituted.

To facilitate the substitution process for missing or invalid H_2S percent, the Fortran program SUMMISS was developed, as shown in the flow chart of Figure 4-2. SUMMISS computes average H_2S percent of all valid entries for each pool for each field, and flags those field-pools for which no valid H_2S-percent data are available, thus accommodating the three substitution schemes discussed above. H_2S-percent substitutions were subsequently made to Work File 1 based on the averages computed by SUMMISS. The H_2S-percent substitution procedure proved cumbersome and time consuming and, in some limited instances, an appropriate substitution value could not be obtained. In a few other cases, a substitution was not made because it was determined that the field/pool was nonproducing for the period of concern (i.e., November 1987-March 1988).

Upon completion of the substitution procedure for missing or invalid H_2S percent, it became apparent that fields where all wells had an H_2S percent of zero for all pools could be eliminated from the work file, and that such purging would more efficiently take place before substitutions were made for other missing parameter values. Because total SO_2 and H_2S emissions would compute to zero, such fields would be of no value to the present Study or any likely further air quality studies. To reduce work file overhead, therefore, Fortran program EXCLUDE was prepared to screen Work File 1 and remove data for all wells associated with fields where all wells had an H_2S percent of zero for all pools. As shown in Figure 4-3, EXCLUDE was executed to produce a pared-down "Work File 2".

Though substitution for missing H_2S-percent data was now complete, missing entries for treater/flare location (legal), footage, and stack height remained in Work File 2. Fortran program WBSSUB was prepared to modify Work File 2 with substitutions for all remaining missing data. Substitution provisions were as follows.

1) Corresponding wellhead location is substituted for missing treater or flare legal location.

2) Corresponding wellhead footage is substituted for missing treater or flare footage.

3) A representative value, 22 feet, is substituted for missing treater stack height.

4) The minimum height necessary to meet AAQS (using single-source dispersion modeling) is substituted for missing flare stack height.

Wellhead location and footage was substituted for missing treater/flare location and footage because it was the only available option. A stack height of 22 feet was substituted for missing treater height because it reflects an industry standard value. Because flare stack heights tend to vary substantially, it was concluded unrealistic to accept a constant value to use for substitution. The regulatory framework, however, is in place to insure that oil and gas facility flares in North Dakota comply with applicable AAQS for SO_2, even though resource constraints means that not all facilities have yet been reviewed to this end yet. Therefore, substitution of sufficient height to achieve compliance with AAQS for SO_2 (according to modeling results on a single-source basis) was concluded to be the best alternative for addressing missing flare stack height. These stack-height substitution provisions were specified in the Cooperative Agreement.

In considering the limitations of the above substitution provisions and potential impact on modeling accuracy, it should be noted that field inspections were conducted to obtain actual measurements of treater/flare location and stack height for the twelve subject fields of the Williston Basin Study. As explained in Section 4.3.3, emissions inventory data for location and stack height were used as model input only for nearby fields which were modeled in addition to the subject field to account for possible interactive air quality impact. Thus, even though the above substitution provisions may yield some inaccuracy in modeling the contribution of nearby-field emissions, use of actual measured data for model input for subject-field wells (which will clearly contribute more to model predictions than nearby wells) should significantly mitigate these inaccuracies in the context of overall model results.

Program WBSSUB was executed to effectuate the substitution provisions for treater/flare location, footage, and stack height. As indicated in Figure 4-2, execution of WBSSUB resulted in the creation of "Work File 3". Work File 3 reflects a "clean" work file with no missing data, and with all necessary parameters for derivation of the final emissions inventory.

Substitution provisions for all parameters with missing entries, i.e., H_2S percent, treater/flare location, treater/flare footage, and treater/flare stack height, are summarized in Table 4-5.

TABLE 4-5
Substitution Provisions for Missing Data

Parameter	Substitution
H_2S Percent (missing or invalid)	In order of priority: 1 The average of all valid entries (H_2S Percent) from the same field and pool. 2 The average of all valid entries for the same pool from a nearby field. 3 The average of all valid entries for a geologically similar pool from a nearby field.
Treater/Flare Location (missing)	Wellhead location
Treater Stack Height (missing)	22 feet
Flare Stack Height (missing)	Minimum height necessary to meet AAQS

4.2.2.3 Derivation of Final Inventory Parameters

Though the Table 4-3 (required inventory) parameters well identification number, field name, treater height, and flare height were explicitly present in Work File 3, the Table 4-3 parameters treater/flare SO_2 emission rate, treater/flare heat of combustion, and well PSD status had to be derived from other work file elements. In addition, the treater/flare legal description (location) in the work file had to be converted to cartesian coordinates to accommodate dispersion model input requirements.

The Universal Transverse Mercator (UTM) coordinate system was selected for referencing and mapping source and receptor locations for the Williston Basin Study. The UTM system was selected because it is a cartesian coordinate mapping system, it is routinely used by the NDSDH for dispersion modeling analyses, it is implemented on United States Geological Survey (USGS) maps which were referenced for several aspects of the Williston Basin Study, and because the State has a computer procedure to convert legal-footage descriptions to UTM coordinates.

Because the State's conversion procedure constitutes a special system requiring special access, the conversion of legal-footage descriptions to UTM coordinates had to be addressed separately from the

preparation of other inventory parameters. The conversion was a two step process. First, as shown in Figure 4-2, Fortran program UTMPREP was prepared and applied to Work File 3. UTMPREP extracts the legal-footage description of each well from Work File 3 and writes the descriptions to a file in the format required by the UTM-conversion computer procedure. Second, the computer procedure was executed to create a work file of UTM coordinates. This is also shown in Figure 4-2.

Derivation of remaining inventory parameters, and preparation of the final emissions inventory, was accomplished with the preparation and execution of Fortran program WBSINV. The most significant tasks performed by program WBSINV are:

1) Calculates treater SO_2 emission rate using work file H_2S percent, monthly lease-use gas production, and monthly days of production.

2) Calculates flare SO_2 emission rate using work file H_2S percent, monthly vent-flare gas production, and monthly days of production.

3) Calculates treater heat of combustion from work file monthly lease-use gas production and monthly days of production.

4) Calculates flare heat of combustion from work file monthly vent-flare gas production and monthly days of production.

5) Determines well PSD status using the work file completion date.

6) Writes the final emissions inventory file, with required content and format, for North Dakota wells.

The expressions used to calculate treater/flare SO_2 emission rate and heat of combustion are derived in Table 4-6. Summation signs in the equations imply summing of monthly values for the five-month period November 1987 through March 1988 (calculations were also performed on a single-month basis). For calculation of treater SO_2 emission rate or treater heat of combustion, monthly gas production implies monthly lease-use gas production. For calculation of flare SO_2 emission rate or flare heat of combustion, monthly gas production implies monthly vent-flare gas production. Based on the NDSDH's experience with gas-component analyses for wells in North Dakota, 302400 cal/ft^3 (1200 BTU/ft^3) was determined to be a representative heating value appropriate for use in the heat of combustion calculation.

Well PSD status was determined using the earliest completion date for any pool from which that well has produced. Well SO_2 emissions were considered PSD-increment-consuming if the earliest completion date occurred after the PSD baseline date, December 19, 1977. This simplification is not totally accurate, because of the possibility of wells completing into one pool before the baseline date and into another pool after. In such cases, any increase (decrease) in SO_2 emissions over the emission rate as of the baseline date does technically consume (add) PSD increment. Because the Industrial Commission's oil and gas data base includes very limited production data for 1977, however, it was not possible to determine the PSD-increment-consuming portion of the SO_2 emissions in these cases.

Execution of program WBSINV produced both a complete emissions inventory computer file and an abbreviated inventory printout, as illustrated in Figure 4-2. Content and format of the computer inventory is described in Table 4-7. As shown in Table 4-7, the final inventory includes other parameters in addition

to the required parameters identified in Table 4-3. The additional parameters were included so that any recipient of the computer file would be able to reproduce the derivation of required parameters. Also, substitution codes were included to indicate if a substitution was made for missing location, stack height, or H_2S percentage.

TABLE 4-6
Computation of Treater/Flare
SO_2 Emission Rate and Heat of Combustion*
(North Dakota Wells)

$$SO_2\ (g/sec) = \frac{\sum \text{Monthly Gas Production } (ft^3)}{\sum \text{Monthly Days of Prod. x } 86{,}400 \text{ sec/day}} \times \frac{H_2S\%}{100} \times \frac{1 \text{ lb-mole}^{**}}{379\ ft^3\ H_2S} \times \frac{29{,}030\ g\ SO_2}{\text{lb-mole}}$$

$$= \frac{\sum \text{Monthly Gas Production } (ft^3) \times H_2S\ \% \times 8.865 \times 10^{-3}}{\sum \text{Monthly Days of Production}}$$

$$\text{Heat of Comb. (cal/sec)} = \frac{\sum \text{Monthly Gas Production } (ft^3)}{\sum \text{Monthly Days of Prod. x } 86{,}400 \text{ sec/day}} \times \frac{302{,}400\ cal^{***}}{ft^3}$$

$$= \frac{\sum \text{Monthly Gas Production } (ft^3) \times 3500}{\sum \text{Monthly Days of Production}}$$

*Summation signs in the equations imply summing of monthly values for November 1987 - March 1988. Results of above expressions were summed for all pools if well operating on commingled basis. Gas production implies lease-use gas production for treater calculations and vent-flare gas production for flare calculations.

**379 ft^3 H_2S per lb-mole @ 60°F

***302,400 cal/ft^3 (1200 BTU/ft^3) reflects typical heating value for study area wells.

TABLE 4-7
Content and Format of
Emissions Inventory for Existing Wells*

Parameter	Format	Description or Comments
Field Name	A20	Name of oil and gas field.
File Number	I5	Unique well identifier state-wide.
Well Name	A30	Well name.
Well Number	A10	Unique well identifier within field.
Well Location	A12	Generally in the form QQQQSSTTTRRR where QQQQ is the quarter-quarter section, SS is the section, TTT is the township and RRR is the range (e.g., SESW36161095 = southeast quarter of southwest quarter of section 36, township 161 north, range 95 west).
Well Footage	A14	Distance in feet from nearest section line for both N-S and E-W directions (e.g., 1980FNL0660FEL = 1980 feet from north line and 660 feet from east line).
UTM Coord. East	I6	(meters)
UTM Coord. North	I7	(meters)
UTM Zone	I2	Zone is 13 or 14 in North Dakota.
Treater: (The next 12 parameters pertain to the treater)		
Location	A12	Refer to well location.
Footage	A14	Refer to well footage.
UTM Coord. East	I6	(meters)
UTM Coord. North	I7	(meters)
UTM Zone	I2	
Substitution Code	I1	= 1 if a substitution was made for missing location; = 0 otherwise.
Stack Height	I3	(feet)
Substitution Code	I1	= 1 if a substitution was made for missing stack height; = 0 otherwise.
SO_2 Emission Rate Average	F7.3	Five-month average (g/sec).
SO_2 Emission Rate Monthly	5F7.3	Monthly SO_2 values for November 1987 through March 1988
Heat of Combustion Average	F9.0	Five-month average (cal/sec).
Heat of Combustion Monthly	5F9.0	Monthly heat of combustion values for November 1987 through March 1988

TABLE 4-7 (cont.)

Parameter	Format	Description or Comments
Flare: (The next 12 parameters pertain to the flare)		
Location	A12	Refer to well location.
Footage	A14	Refer to well footage.
UTM Coord. East	I6	(meters)
UTM Coord. North	I7	(meters)
UTM Zone	I2	
Substitution Code	I1	= 1 if a substitution was made for missing location; = 0 otherwise.
Stack Height	I3	(feet)
Substitution Code	I1	= 1 if a substitution was made for missing stack height; = 0 otherwise.
SO_2 Emission Rate Average	F7.3	Five-month average (g/sec).
SO_2 Emission Rate Monthly	5F7.3	Monthly SO_2 values for November 1987 through March 1988
Heat of Combustion Average	F9.0	Five-month average (cal/sec).
Heat of Combustion Monthly	5F9.0	Monthly heat of combustion values for November 1987 through March 1988
Number of Pools	I1	Ranges from 1-4
The next 7 parameters designate arrays with positions for each of 4 pools, regardless of the actual number of pools indicated above - unused pool positions are zero or blank)		
Pool Name(4)	4A20	
H_2S Percent(4)	4F5.2	H_2S concentration of wellhead gas expressed in percent.
Substitution Code(4)	4I1	= 1 if substitution was made for missing or invalid H_2S data for that pool; = 0 otherwise.
Days of Production(5,4)	20I3	Monthly days of production (from 0 to 31) for each pool for each month (November 1987 through March 1988); pools are grouped together for each month.
Wellhead Gas Production(5,4)	20I7	Total wellhead gas production (in thousand cubic feet) for each pool for each month; pools are grouped together for each month.
Lease-Use Gas Production(5,4)	20I7	Gas production used on lease (in thousand cubic feet) for each pool for each month; pools are grouped together for each month. Used to compute SO_2 emission rate and heat of combustion for treater.
Vent-Flare Gas Production(5,4)	20I7	Gas production vented or flared (in thousand cubic feet) for each pool for each month; pools are grouped together for each month. Used to compute SO_2 emission rate and heat of combustion for flare.

*The inventory includes this set of parameters for each well.

4.2.2.4 Addition of Montana Wells

Necessary Montana well data were acquired to complete the emissions inventory for existing wells. As indicated previously, Montana data were provided by the Montana State Department of Health and Environmental Sciences (MSDHES). The MSDHES provided data via computer diskette file for wells in northeast and east-central Montana. The data file was provided with content and format consistent with the request of the NDSDH[5], and included the following parameters for each well:

Identification Number
Field Name
UTM North (wellhead)
UTM East (wellhead)
Pool Name
Completion Date
H_2S Percent
H_2S Method
Gas Flaring Rate (MCFD)
Gas Lease-Use Rate (MCFD)
Days of Production (January 1987-June 1987)

If a well included more than one pool, a complete set of the above information (i.e., record) was repeated for each pool. Gas flaring rate and gas lease-use rate reflected average values for the six-month period January 1987 through June 1987. Obviously, this period is not consistent with the time frame used for developing the emissions inventory for North Dakota wells (November 1987 through March 1988). The discrepancy came about because the NDSDH recommended to Montana that six-month average values be provided for flaring rate and lease-use rate, but did not specify the time frame. Aware that the MSDHES was dealing with limited data availability, the NDSDH wanted to allow the MSDHES flexibility to provide averages for the period associated with the greatest convenience or data availability. Subsequent to the NDSDH's request to the MSDHES, the BLM suggested the period November 1987 to March 1988 for emissions inventory development[6]. At that point, however, Montana was well underway with data collection for January 1987 through June 1987. In any event, given the distant interactive nature of the Montana wells with respect to the twelve Study fields, it was concluded unlikely that the discrepancy in emission time frames would significantly affect Study results.

To be consistent with the existing emissions inventory developed for North Dakota wells, content and format of the MSDHES file was modified as follows:

1) The file was screened to eliminate wells which were too far away from the twelve Study fields to be of concern in the dispersion modeling analysis.

2) Substitutions were provided for missing data, including H_2S percent and treater/flare stack height.

3) PSD status, SO_2 emission rate, and heat of combustion were derived from DHES file production data.

4) Final Montana-well inventory data were properly formatted and added to the emissions inventory previously developed for North Dakota wells.

The computer file provided by MSDHES included well data for a large portion of northeast and east-central Montana. As discussed in Section 4.3, however, the WBS modeling methodology limited interactive source inclusion to 50 km from subject Study fields. Therefore, as the first step in preparation

of the Montana inventory, the NDSDH screened the MSDHES computer file to eliminate all Montana wells which were more than 50 km away from all twelve Study fields. As shown in the flow chart of Figure 4-3, Fortran program MONTINV was developed to accomplish this step. Program MONTINV also eliminated wells with zero production, and wells for which no location was provided. Execution of MONTINV created "Work File 1", as shown in Figure 4-3.

The NDSDH next addressed missing data in the Montana well file. An entry for H_2S percent was missing for a considerable portion of the Montana wells. The NDSDH used the same substitution schedule here as for the North Dakota wells, i.e.,

1) The average of all valid entries from the same field and pool is substituted.

2) If no valid entries are present for the pool in the same field, the average of all valid entries for the same pool from a nearby field is substituted.

3) If no valid entries are present for the same pool in any nearby field, the average of all valid entries for a geologically similar pool from a nearby field is substituted.

Because of the relatively small number of wells remaining in the MSDHES file, H_2S substitutions were performed manually. Because of the small number of wells in some fields, H_2S percent for the same pool was averaged among several fields to obtain a suitably representative substitution. The H_2S-percent substitution step is noted in Figure 4-3, and resulted in the updated "Work File 2".

The final step in the preparation of the Montana well inventory was to derive treater/flare SO_2 emission rate, treater/flare heat of combustion, and well PSD status from other MSDHES file elements. In addition, substitute values had to be established for treater and flare stack height, parameters which were not included in the MSDHES file. Derivation of remaining Montana inventory parameters and writing of the final Montana emissions inventory file was accomplished with the preparation and execution of Fortran program WBSINVM. Program WBSINVM performs the following:

1) Assigns a value of 22 feet to treater stack height for all wells.

2) Assigns a value of 1 foot to flare stack height for all wells.

3) Assigns corresponding wellhead location (UTM coordinates) for both treater and flare.

4) Calculates treater SO_2 emission rate using work file H_2S percent and six-month average lease-use rate (MCFD).

5) Calculates flare SO_2 emission rate using work file H_2S percent and six-month average flaring rate (MCFD).

6) Calculates treater heat of combustion from MSDHES file lease-use rate (MCFD).

7) Calculates flare heat of combustion from MSDHES file flaring rate (MCFD).

8) Determines well PSD status using the MSDHES file completion date.

9) Writes the final emissions inventory file, with specified content and format, for Montana wells.

As was the case for North Dakota treaters with missing stack height (Section 4.2.2.2), 22 feet was assigned to all Montana treaters because it reflects an industry standard value. Because it was considered inappropriate to assume a flare stack height which allows compliance with AAQS. Rather, for Montana flare stack height, a conservative assumption of one foot was applied. For lack of other information, wellhead location in UTM coordinates was assigned to both treater and flare. Again, given the distance of the Montana wells from the Study fields, it was concluded unlikely that the above assumptions/ simplifications would have a significant impact on dispersion model results.

The expressions used to calculate treater/flare SO_2 emission rate and heat of combustion for Montana wells are derived in Table 4-8. For calculation of treater SO_2 emission rate or treater heat of combustion, six-month average gas rate implies lease-use gas rate. For calculation of flare SO_2 emission rate or flare heat of combustion, six-month average gas rate implies flaring gas rate. These expressions differ from those used to calculate the same parameters for North Dakota wells (Table 4-6) because the gas production information provided by the MSDHES reflected six-month average values with days of production already factored in.

For Montana wells, as for North Dakota wells, SO_2 emissions were considered PSD-increment-consuming if the earliest completion date occurred after the baseline date, December 19, 1977. The North Dakota baseline date was used because all Study-field receptors are located in North Dakota.

As illustrated in Figure 4-3, execution of program WBSINVM produced a complete emissions inventory file for Montana wells with content and format as described in Table 4-7. The Montana emissions inventory file was subsequently appended to the North Dakota file to form the complete emissions inventory for the existing scenarios.

TABLE 4-8
Computation of Treater/Flare
SO_2 Emission Rate and Heat of Combustion*
(Montana Wells)

$$SO_2\ (\text{g/sec.}) = \frac{\text{6-Month Average Gas Rate (ft}^3\text{/day)}}{\text{86,400 sec/day}} \times \frac{H_2S\%}{100} \times \frac{\text{1 lb-mole**}}{\text{379 ft}^3\ H_2S} \times \frac{\text{29,030 g } SO_2}{\text{lb-mole}}$$

$$= \text{6-Month Average Gas Rate (ft}^3\text{/day)} \times H_2S\ \% \times 8.865 \times 10^{-3}$$

$$\text{Heat of Comb. (cal/sec)} = \frac{\text{6-Month Average Gas Rate (ft}^3\text{/day)}}{\text{86,400 sec/day}} \times \frac{\text{302,400 cal***}}{\text{ft}^3}$$

$$= \text{6-Month Average Gas Rate (ft}^3\text{/day)} \times 3500$$

*Results of above expressions were summed for all pools if well operating on commingled basis. Gas rate implies lease-use gas rate for treater calculations and flaring gas rate for flare calculations.

**379 ft^3 H_2S per lb-mole @ 60°F

***302,400 cal/ft^3 (1200 BTU/ft^3) reflects typical heating value for study area wells.

4.2.3 Inventory for Future Scenarios

To create an emissions inventory for a foreseeable-future scenario, assumptions had to be made regarding the location and production/emissions potential of future oil and gas wells. Initially, it was concluded sufficient to project future (foreseeable-future) well locations and production data for the twelve Study fields (Table 4-1) only. It became apparent based on the results of a sensitivity analysis[9], however, that the interactive potential of future SO_2 emissions from several other nearby fields necessitated that these fields be incorporated into the emissions inventory and dispersion modeling analysis for future wells. These additional fields are:

Bear Den	North Elkhorn Ranch
Buckhorn	Oakdale
Devils Pass	Red Wing Creek
Grassy Butte	Teddy Roosevelt (T.R.)
Morgan Draw	Tree Top

It was concluded that additive impact of future emissions from other fields would be insignificant because of their distance from the Study fields, or because of low emissions potential. Oil and gas fields included in the foreseeable-future emissions inventory are summarized in Table 4-9.

TABLE 4-9
Oil and Gas Fields Included in
Emissions Inventory for Foreseeable Future

Original Twelve Study Fields:	
Big Stick	Lost Bridge
Buffalo Wallow	Rough Rider
Charlson	Scairt Woman
Elkhorn Ranch	Smith
Little Knife	Stanley
Lone Butte	Whiskey Joe
Additional Ten Nearby Fields:	
Bear Den	North Elkhorn Ranch
Buckhorn	Oakdale
Devils Pass	Red Wing Creek
Grassy Butte	Teddy Roosevelt (T.R.)
Morgan Draw	Tree Top

Projections of future well locations for study fields and the additional fields noted above were provided by the BLM. Using geological assessment of areas most favorable for further oil and gas exploration, the BLM determined which available spacing units* could reasonably contain new producing wells in the foreseeable future. These spacing units were identified in pool-specific maps provided to the NDSDH[10,11]. The NDSDH subsequently projected which future wells would include SO_2-emitting treaters (fueled with lease-use gas) or active flares.

*A spacing unit approximates the expected drainage radius, from the wellbore, for a particular pool. It is based on reservoir characteristics and is administered by the SIC to protect correlative rights and prevent unnecessary waste.

Estimates of future well production/emissions potential were developed by the NDSDH, and were based on production/emissions data for existing wells in the same area. In general, the SO_2 emission rate and heat of combustion for a treater/flare associated with a future well was taken as the average of that of all treaters/flares associated with existing wells in the same field and pool, or the same pool in a nearby field. To fulfill the Table 4-3 requirements for a WBS emissions inventory, the NDSDH also made assumptions regarding the treater and flare stack height for future wells (Section 4.2.3.2).

As in the case of the emissions inventory for existing wells, an extensive computer software system was developed to perform necessary tasks associated with construction of the emissions inventory for future wells. This system is illustrated in Figure 4-4. A description of the specific procedures used to develop the emissions inventory for future wells, and of the associated components of Figure 4-3, follows in Sections 4.2.3.1 - 4.2.3.3.

4.2.3.1 Facility Locations

As indicated previously, BLM personnel made projections of future oil and gas well locations. These projections were based on areas where geological evidence supported future drilling activity. The BLM determined which available spacing units could reasonably contain new producing wells in the foreseeable future, and provided maps identifying these spacing units for the applicable fields (twelve Study fields plus the ten additional fields noted above). The BLM prepared separate maps for each plausible pool within each field. An example of a BLM future-location map for the Stanley field is shown in Figure 4-5.

In utilizing the BLM maps to construct a future emissions inventory, it was concluded inappropriate to assume that all future well installations would include a lease-use-gas fired treater with potential SO_2 emissions. This conclusion was based on experience with the existing emissions inventory, where some well treaters have zero emission potential because they are fired on pipeline (processed) or propane gas. Likewise, it was concluded inappropriate to assume that all future well installations would include active flares (vent-flare production = 0), because all wellhead gas for some wells may be piped to a central gas processing plant. It seemed more reasonable to assume continuity within a field (on a pool-specific basis) of operators who fire treaters on lease-use gas versus operators who fire treaters with alternative fuel, and continuity of operators who divert gas to a central gas processing plant versus operators who flare on-site. Based on a lack of information which would support a more subjective approach, therefore, it was decided that:

1) within a given field-pool environment (i.e., for each pool within each field), the proportion of lease-use-gas fired treaters (lease-use treaters) to total producing wells for the future emissions inventory should equal that same proportion for the existing inventory, and

2) within a given field-pool environment, the proportion of active flares to total producing wells for the future emissions inventory should equal that same proportion for the existing inventory.

Having decided on an approach for allocating the number of future lease-use treaters and active flares in each field, the next step in developing the future inventory was to assign allocated lease-use treaters and active flares to specific future well locations. Again, based on a lack of information which would support a more subjective approach, it was decided to allocate lease-use treaters and active flares to future wells in a random manner within a given field-pool. It was also concluded inappropriate to assume any centralized processing (commingled) facilities for the future inventory (i.e., it was assumed each well has its own, on-site processing facilities).

FIGURE 4-4

EMISSIONS INVENTORY

CREATION SYSTEM:

FUTURE WELLS

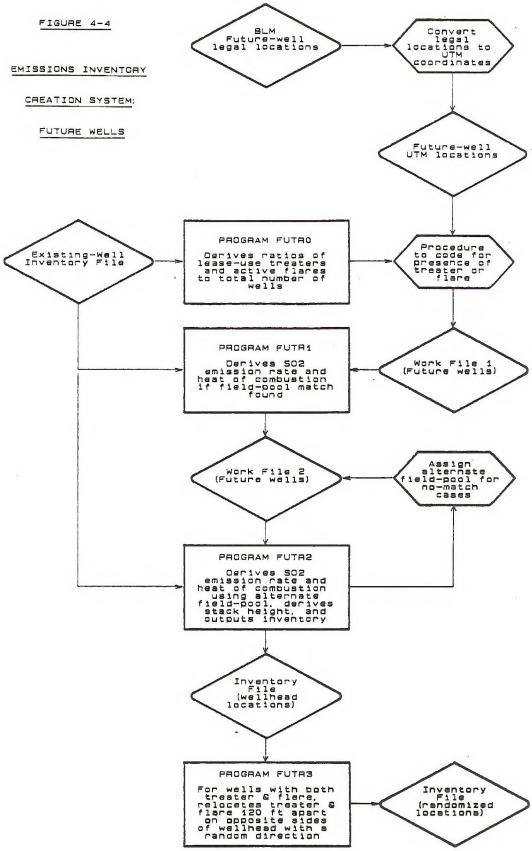
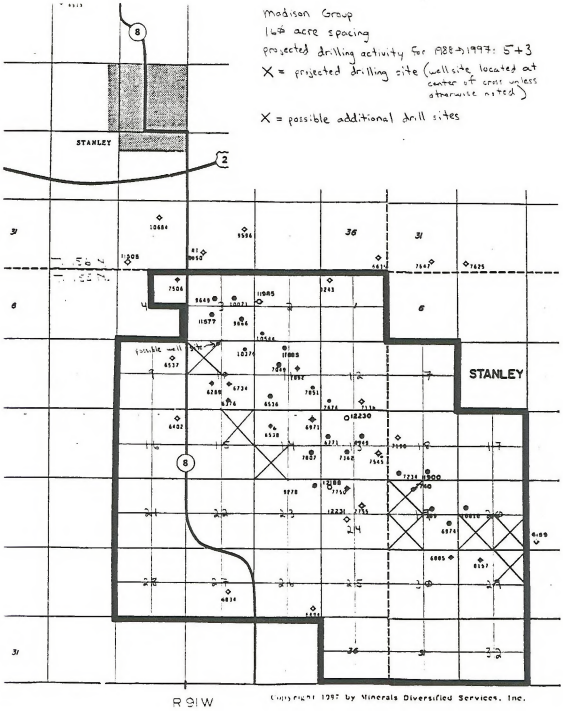


Figure 4-5
BLM Future Well Location Map*
for Stanley Field, Madison Pool



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*Base map prepared by Minerals Diversified Services, Inc., Bismarck, ND.

The specific procedure used to establish future treater and flare locations was as follows:

1) The future well location maps provided by the BLM were used to create a computer work file which included a legal description location and pool name for each projected spacing unit.

2) The State's coordinate conversion system was applied to the future-well-location work file to convert well legal descriptions to UTM coordinates. The resultant UTM coordinates reflected the center of projected spacing units. This procedure is identified in the flow chart of Figure 4-4.

3) The emissions inventory for existing wells was used to derive the ratio of lease-use treaters to total producing wells and the ratio of active flares to total producing wells. This ratio was derived on an overall basis, and also on a pool-specific basis, for each field. This step was accomplished with the assistance of Fortran program FUTR0, which totaled the number of existing producing wells, lease-use treaters, and active flares for each pool in each field (Figure 4-4).

4) To determine the number of future lease-use treaters and active flares which would be allocated for each pool within each field, the ratios determined in Step 3 (above) were multiplied by the total number of future wells projected by the BLM on a pool-specific basis for each field. If the number of existing wells for the pool was five or greater, the pool-specific ratio was used. If the number of existing wells for the pool was less than five, the overall field-average ratio was used. As implied, less than five wells for a pool was considered too small a sample to develop a meaningful treater or flare ratio for that pool.

As an example of the allocation strategy outlined in Steps 3 and 4, above, consider the procedure for the Elkhorn Ranch Field. BLM future projection maps for Elkhorn Ranch included wells in the Bakken, Madison, and Red River pools. For these pools, the following information was obtained (program FUTR0) from the emissions inventory for existing Elkhorn Ranch wells:

Pool	*Producing Wells*	*Lease-Use Treaters*	*Active Flares*
Madison	24	23	22
Bakken	19	19	3
Red River	0	0	0

The ratios calculated for Step 3 are:

Pool	*Lease-Use Treaters/ Producing Wells*	*Active Flares/ Producing Wells*
Madison	.96	.92
Bakken	1.00	.16
Red River	.00	.00
Overall	.98	.58

The number of future wells projected by the BLM for the Elkhorn Ranch Madison, Bakken, and Red River pools are 12, 20, and 2, respectively. The Step 4 calculations thus give:

Pool	*Future Lease-Use Treaters*	*Future Active Flares*
Madison	12 x .96 = 12	12 x .92 = 11
Bakken	20 x 1.0 = 20	20 x .16 = 3
Red River	2 x .98 = 2	2 x .58 = 1

Note that calculations for the Red River pool incorporated the overall field ratios, because the existing inventory included fewer than five wells for that pool.

The number of future wells projected, lease-use treaters allocated, and active flares allocated for each pool within each of the twelve Study fields and ten additional nearby fields are summarized in Table 4-10.

Continuing with the procedure for establishing future treater and flare locations:

5) A randomizing procedure was used to distribute allocated lease-use treaters and active flares among the future well locations in the work file. Randomizing was performed on a pool-specific basis for each field. For each well location in the work file, a code number was added to indicate the status of the well installation:

   0 = does not include lease-use treater or active flare
   1 = includes lease-use treater, only
   2 = includes lease-use treater and active flare
   3 = includes active flare, only

   The randomizing processes for lease-use treater locations and active flare locations were executed independently of each other. Therefore, the presence of a lease-use treater for a given future well had no bearing on (did not enhance or decrease) the potential for locating an active flare at the same future well, and vice versa. The randomizing/coding procedure is noted in the flow chart of Figure 4-4.

Completion of above Steps 1 through 5 resulted in a computer work file (Work File 1 in Figure 4-4) which included field name, UTM coordinates, pool name, and code (for presence of lease-use treater or active flare) for each future well.

4.2.3.2 Derivation of Other Inventory Parameters

To fulfill the WBS emissions inventory requirements outlined in Table 4-3, an identification number, treater/flare stack height, treater/flare SO_2 emission rate, and treater/flare heat of combustion also had to be determined for future wells (PSD status was not necessary because any future well will clearly consume PSD increment). As indicated previously, values for these future well parameters were derived from the emissions inventory for existing wells. The following protocol was used:

1) Future treater SO_2 emission rate was computed as the average SO_2 emission rate for all existing lease-use treaters from the same field and pool. If no existing lease-use treaters were present for the same pool in the same field, the average for all existing lease-use treaters for the same pool from a nearby field was substituted.

TABLE 4-10
Future Wells Projected, Lease-Use Treaters Allocated, and Active Flares Allocated for Each Pool of Each Field

Field	Pool	Number of Wells	Number of Lease-Use Treaters	Number of Active Flares
Big Stick	Madison	6	5	1
	Bakken	6	5	1
	Duperow	5	4	1
	Red River	2	2	0
	Total	19	16	3
Buffalo Wallow	Madison	4	1	1
	Duperow	4	1	1
	Red River	1	0	0
	Total	9	2	2
Charlson	Madison	2	0	0
	Bakken	12	0	2
	Red River	7	0	1
	Interlake	10	0	1
	Total	31	0	4
Elkhorn Ranch	Madison	12	12	11
	Bakken	20	20	3
	Red River	2	2	1
	Total	34	34	15
Little Knife	Madison	19	9	3
	Bakken	2	1	0
	Duperow	5	2	1
	Red River	1	0	0
	Total	27	12	4
Lone Butte	Madison	4	2	1
	Red River	2	1	0
	Total	6	3	1
Lost Bridge	Madison	1	1	1
	Bakken	3	3	2
	Duperow	6	6	4
	Red River	2	2	1
	Total	12	12	8
Rough Rider	Madison	11	10	9
	Bakken	7	6	6
	Duperow	4	3	4
	Red River	6	5	5
	Total	28	24	24

TABLE 4-10 (cont.)

Field	Pool	Number of Wells	Number of Lease-Use Treaters	Number of Active Flares
Scairt Woman	Madison	2	2	2
	Duperow	2	2	2
	Red River	1	1	1
	Gunton	2	2	2
	Total	7	7	7
Smith	Madison	3	3	2
	Total	3	3	2
Stanley	Madison	8	8	3
	Total	8	8	3
Whiskey Joe	Madison	8	7	1
	Duperow	3	3	0
	Total	11	10	1
Bear Den	Madison	3	2	1
	Red River	1	1	0
	Total	4	3	1
Buckhorn	Madison	2	2	1
	Bakken	5	4	1
	Total	7	6	2
Devils Pass	Madison	4	4	1
	Duperow	2	2	0
	Total	6	6	1
Grassy Butte	Madison	5	5	1
	Total	5	5	1
Morgan Draw	Madison	3	3	0
	Total	3	3	0
North Elkhorn Ranch	Madison	2	2	1
	Total	2	2	1
Oakdale	Madison	2	2	2
	Total	2	2	2
Red Wing Creek	Madison	2	2	0
	Total	2	2	0
T.R.	Madison	2	2	0
	Total	2	2	0
Tree Top	Madison	1	1	0
	Total	1	1	0

2) Future flare SO_2 emission rate was computed as the average SO_2 emission rate for all existing active flares from the same field and pool. If no existing active flares were present for the same pool in the same field, the average for all existing active flares for the same pool from a nearby field was substituted.

3) Future treater heat of combustion (HOC) was computed as the average HOC for all existing lease-use treaters from the same field and pool. If no existing lease-use treaters were present for the same pool in the same field, the average for all existing lease-use treaters for the same pool from a nearby field was substituted.

4) Future flare HOC was computed as the average HOC for all existing active flares from the same field and pool. If no existing active flares were present for the same pool in the same field, the average for all existing active flares for the same pool from a nearby field was substituted.

5) All future treater stack heights were set at 22 feet, an industry standard value.

6) Future flare stack height was set to the minimum height necessary to meet AAQS (using single-source dispersion modeling).

Based on the treater/flare code in the work file, the above protocol was applied only to future wells for which a lease-use treater and/or active flare was assigned (treater/flare code 0). Future wells with no lease-use treaters or active flares (i.e., with zero emissions potential) were eliminated from the inventory.

Development of future treater/flare SO_2 emission rate and heat of combustion from pool-specific field averages of existing values was considered the most viable option. Another option which was considered was to establish a spatial trend in existing emissions within a field-pool, and subsequently vary future well treater/flare emissions based on that well's location within the field. However, the logistical implications of attempting to establish spatial trends for all field-pools would have been overwhelming, and it is not clear that such trends were consistently present anyway. There was evidence in the existing inventory that production and SO_2 emissions for many field-pool environments varied randomly in a spatial sense. Hence, the simpler approach utilizing pool-specific field averages for existing wells was adopted.

A stack height of 22 feet was assumed for future treaters because it reflects an industry standard value, and is the same value substituted for missing treater stack height in the existing inventory. As was the case for missing flare heights in the existing inventory, it was concluded that a constant flare stack height for future wells could not be assumed because of the current variability of stack height in the field. But again, the regulatory framework is in place in North Dakota to ensure that future oil and gas facility flares comply with applicable AAQS for SO_2. Therefore, future flare stack height was set to the minimum height necessary to meet AAQS.

A computer procedure was set up to implement the inventory-preparation protocol (Items 1-6) described above. Fortran programs FUTR1 and FUTR2, as shown in Figure 4-4, were created for this procedure. Program FUTR1 accesses the future well work file (Work File 1) and the existing emissions inventory file to provide an SO_2 emission rate and HOC for each future treater and flare based on the criteria discussed above. FUTR1 does not compute an SO_2 emission rate or HOC, however, if it cannot find a matching field-pool (which includes lease-use treaters or active flares) in the existing inventory. FUTR1 merely flags such events, and subsequent application of program FUTR2 allows the user to substitute the name of a nearby field for average SO_2 emission rate and HOC calculations, consistent with the protocol outlined above. If the substitute field still does not include lease-use treaters or active flares in the same

pool, FUTR2 allows the user to continue substituting field names on an iterative basis until existing lease-use treaters or active flares are found for all future SO_2 emission rate and HOC calculations. Program FUTR2 also provides a stack height value for each future treater and flare, as specified in protocol Items 5 and 6.

As shown in Figure 4-4, successful execution of program FUTR2 resulted in an output file which reflected a nearly final emissions inventory for future wells. The inventory included treater/flare identification number, UTM coordinates (wellhead), SO_2 emission rate, HOC, and stack height for each future well to which a lease-use treater or active flare was assigned.

4.2.3.3 Modification of Treater/Flare Location

At this point in the preparation of the future emissions inventory, the inventory file was complete with respect to the Table 4-3 required parameters, but UTM coordinates for both treater and flare reflected the wellhead location. To achieve more realistic (less conservative) dispersion modeling results, and to be consistent with Federal spacing requirements[12], the inventory was modified to separate the treater and flare by 120 feet when both lease-use treater and active flare were present at a future well location in the inventory. In such cases, the treater and flare were located 120 feet apart on opposite sides of the wellhead at a randomly derived azimuth. This modification was accomplished with the preparation and execution of Fortran program FUTR3, as shown in Figure 4-4.

Execution of program FUTR3 marked the final step in the preparation of the emissions inventory for future wells. Content and format of the final future inventory is outlined in Table 4-11.

TABLE 4-11
Content and Format of
Emissions Inventory for Future Wells

Parameter	Format	Description or Comments
Identification Number	I5	Unique well identifier, which includes a code to indicate whether parameters which follow are for treater or flare (one set of data (record) is included for each lease-use treater and active flare).
Field Name	A20	Name of oil and gas field.
UTM Coord. East	I8	(meters)
UTM Coord. North	I8	(meters)
UTM Zone	I4	Zone is 13 or 14 in North Dakota.
Stack Height	I4	(feet)
SO_2 Emission Rate	F9.3	(g/sec)
Heat of Combustion	F8.0	(cal/sec)

4.3 Modeling Ambient and PSD Class II SO_2 Scenarios

This Section describes the dispersion (air quality) modeling analysis which was applied to predict maximum potential SO_2 concentrations for the first four Williston Basin Study Scenarios (i.e., existing ambient, future ambient, existing PSD Class II, future PSD Class II). Because the same dispersion model would be applied for each scenario, model input data were largely similar for each scenario, and the NDSDH was concerned that substantial computer resources would be required for the Study, it was concluded more efficient to group these four scenarios into one modeling procedure. The flexibility of the dispersion model selected for use with these scenarios (ISCST) also affected this decision.

The modeling methodology employed for the SO_2 ambient and PSD Class II scenarios was based on recommendations in the EPA Guideline on Air Quality Models (Revised)[13,14] and in the North Dakota Guideline for Air Quality Modeling Analyses[15]. Modeling methodology includes selection of an appropriate dispersion model, and the selection and preparation of input data required to execute such model. At a minimum, input requirements of dispersion models include certain source data, receptor data, meteorological data, and user selection of some model operating parameters. General air quality modeling procedure is depicted in Figure 4-6.

The modeling methodology applied for the WBS ambient and PSD Class II scenarios is outlined in Section 4.3.1, and is described in detail in Sections 4.3.2 - 4.3.8. The WBS modeling procedure is also depicted in the flow chart of Figure 4-7.

Due to the very large number of sources and receptors involved, the modeling analysis for the ambient and PSD Class II scenarios (the bulk of the overall modeling effort) represented an enormous task. Completion of model input preparation and model execution for all twelve Study fields spanned about four months and required about 900 hours of actual clock time on the NDSDH's Compaq 386 desktop computer. Cost for the equivalent work on the State's mainframe computer would have been about $800,000.

4.3.1 Methodology Outline

A. Dispersion Model

1) The EPA Industrial Source Complex Short Term (ISCST)[16] model was selected over other candidate models because of its versatility in generating receptor grids, because of its versatility in grouping sources to project pollutant concentrations for more than one scenario, because it can accommodate area sources, because it is computationally efficient, and because it has proven performance capability[17].

2) The ISCST model requires source data (location, pollutant emission rate, stack height, stack diameter, stack gas exit velocity, and stack gas exit temperature for each emission source), receptor data, representative meteorological data, and user selection of some technical options before it can be executed.

B. Source Data

1) Analysis of each of the twelve Study fields was treated as a separate modeling problem, with separate sets of source input data.

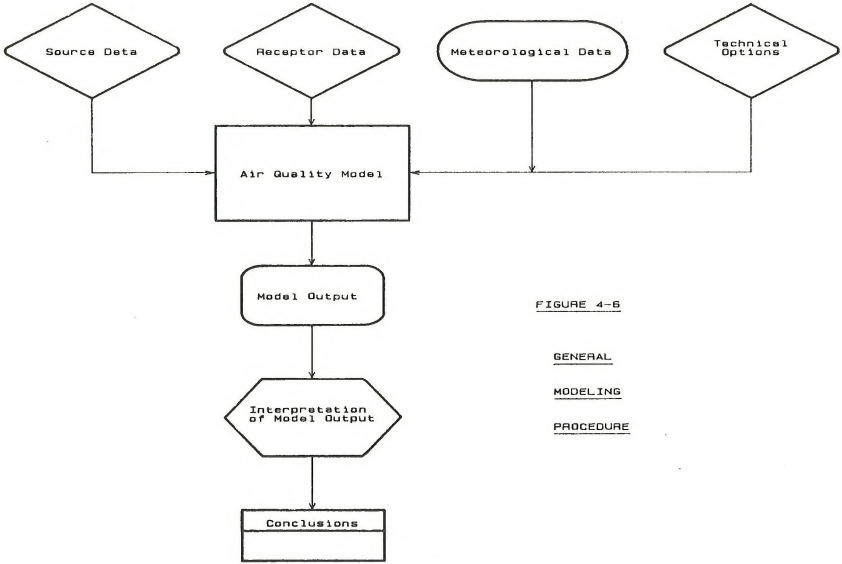


FIGURE 4-6

GENERAL

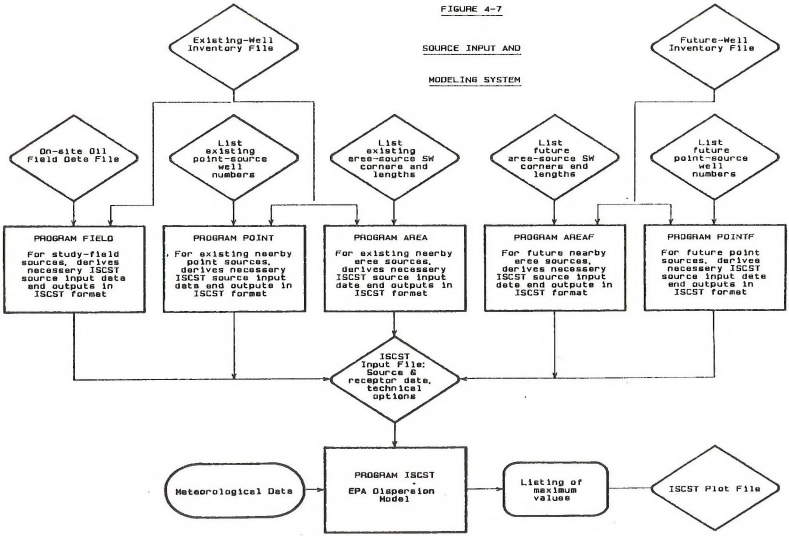
MODELING

PROCEDURE

FIGURE 4-7

SOURCE INPUT AND

MODELING SYSTEM



2) For each Study field, source data included nearby, potentially interactive sources as well as the treaters and flares within the Study field, itself. The inclusion of nearby, interactive sources (outside of the subject field) was limited to well installations and other significant SO_2 sources within 50 km of the center of the subject field. The contribution of SO_2 sources beyond 50 km was accounted for with a background concentration added to model results (F below).

3) For treaters and flares within each subject field, specific location and stack height was determined through on-site measurement (i.e., field inspection). Location and stack height for nearby treaters and flares (outside of the subject field) was taken from the emissions inventory developed in Section 4.2.

4) The SO_2 emission rate for all treaters and flares (subject-field and nearby) was taken from the emissions inventory developed in Section 4.2.

5) Using the procedure described in the North Dakota Guideline for Air Quality Modeling Analyses, virtual values for stack diameter, stack gas exit velocity, and stack gas exit temperature for all treaters and flares were derived from the emissions inventory heat of combustion developed in Section 4.2.

6) To improve model computational efficiency, interactive sources in the vicinity (within 50 km) of the subject field were grouped together as single area sources to the extent practical.

7) The effective emission height for area sources (required model input for area sources) was determined by calculating a weighted-average (weighted by emission rate) exit velocity for the treaters and flares located within the designated area, then using the model plume rise equations to calculate the final plume rise corresponding to this exit velocity (assuming worst-case meteorological conditions). This plume rise was added to the weighted-average stack height (treaters and flares) to obtain the final effective emission height.

8) Area-source SO_2 emission rate was determined by combining the emission rate of individual treaters and flares within the designated area.

C. Receptor Data

1) Cartesian receptor grids were utilized.

2) For each subject field, the receptor grid was defined by a rectangle which is slightly larger than necessary to contain the entire field.

3) Receptor spacing for initial model runs was generally set at 200 meters, but may be greater within open areas of the field where no treaters or flares are present.

4) Additional model runs with refined receptor spacing were conducted for local areas where the initial runs revealed "hot spots" with relatively high concentrations. Refined receptor spacing was no greater than 100 meters.

5) Uneven terrain was not accounted for, i.e., elevation for all sources and receptors was set to zero.

D. Meteorological Data

1) One year of National Weather Service (NWS) hourly meteorological data was utilized.

2) The 1983 Williston surface/Bismarck upper-air NWS meteorological data set is representative of and was used for the entire Study area.

3) To demonstrate the representativeness of the 1983 meteorological data set, additional model runs using other years of Williston surface/Bismarck upper-air NWS meteorological data were conducted for one Study field.

E. Model Technical Options

1) With the exception of treatment of stack-tip downwash and gradual plume rise, ISCST Technical Options were deployed according to standard EPA guidance.

2) Stack-tip downwash were not deployed because a virtual (not physically meaningful) exit velocity was used for treaters and flares.

3) Gradual plume rise were deployed because it is technically more appropriate (than final rise) given the low-level emissions of treaters and flares.

F. Background Concentrations

1) A background concentration was added to dispersion modeling results to account for the contribution of natural SO_2 sources, and the contribution of anthropogenic SO_2 sources beyond 50 km from the center of the subject field.

2) Background concentrations were derived from SO_2 data collected at the NDSDH's Dunn Center monitoring site.

Modeling methodology is discussed in detail in Sections 4.3.2 - 4.3.8.

4.3.2 Model Selection

The Williston Basin Study (ambient and PSD Class II SO_2 scenarios) reflects a dispersion modeling problem which includes many pollutant (SO_2) sources, includes many receptors due to the necessity of a dense receptor grid, is characterized by a rural environment, and is regional in scope. The modeling solution for such a problem might logically incorporate a dynamic, regional-scale dispersion model. Dynamic models simulate pollutant advection and dispersion using meteorology which varies on a temporal and spatial basis, and are thus capable of rendering realistic results even at relatively great source-receptor distances. The disadvantage of such models, however, is that computer resource requirements are substantial, with the cost of execution becoming prohibitive when large numbers of sources or receptors are involved.

The decision to treat each of the twelve Study fields as a separate modeling problem lent flexibility to the model selection process. The modeling problem for each field became local, rather than regional, in scope, which facilitated application of a steady-state model. As implied, temporally and spatially constant meteorology controls advection and dispersion for a given episode in steady-state models. The advantage of steady-state models is that they are economical to use, while providing results which may be more accurate than dynamic models on a local basis. The disadvantage of steady-state models is the areal limitation of application, with EPA suggesting that predictions from such models become tenuous beyond 50 km from the source of emission.

The following factors favored the use of a steady-state model for the Ambient and PSD Class II SO_2 analyses:

1) All twelve Study fields are relatively small, so the areal coverage of receptor grids would be correspondingly localized (receptor coverage no more than 30 km in the longest dimension for the largest field).

2) The NDSDH concluded that SO_2 emission sources farther than 50 km from the center of Study fields could be realistically accounted for with a background concentration.

3) Given the large number of sources and receptors associated with the WBS Ambient and PSD Class II scenarios, the NDSDH realized that even the use of a steady-state model would be straining available computer resources.

The NDSDH therefore elected to use a steady-state model for ambient and PSD Class II SO_2 scenarios.

Candidate steady-state models considered were limited to those recommended by EPA for regulatory use, because the NDSDH has experience with their capability and use. Two EPA-recommended models are applicable to problems involving multiple sources in rural environments. These are the Industrial Source Complex Short Term (ISCST) model[16] and the Multiple Point Source with Terrain (MPTER) model[18,19]. Though both models have scored favorably in performance evaluation tests, ISCST was seen as the preferred choice for the Williston Basin Study because:

1) ISCST offers more versatility in generating receptor grids than MPTER.

2) ISCST allows the user to group sources so that concentrations for more than one scenario can be produced from a single model run. MPTER does not have this capability.

3) ISCST can accommodate area sources; MPTER cannot.

4) Despite its larger computer code, ISCST appears to be more computationally efficient than MPTER.

The ISCST model was therefore selected for use in the WBS Ambient and PSD Class II SO_2 scenarios.

The ISCST model is based on the standard gaussian algorithm. This algorithm assumes that the pollutant maintains a gaussian (bell-shaped) distribution, both in the horizontal and vertical, within the effluent plume one-hour-averaged cross-section, and that the density of pollutant material within a plume segment is inversely proportional to wind speed. Advection and dispersion of effluent material in ISCST is controlled by steady-state meteorology, i.e., it is assumed that the same meteorological conditions persist

long enough for an effluent parcel to travel from the emission point to the farthest receptor of concern. The model utilizes an effective plume height which is the sum of the stack height and calculated plume rise. Plume rise calculations are based on the Briggs equations[20,21].

The ISCST model requires input of sequential, hourly meteorological data including wind speed, wind direction, ambient temperature, stability class, and mixing height. Using these hourly meteorological data, solution of model equations directly yields one-hour average pollutant concentrations. Concentrations for other averaging periods (e.g., 3-hour, 24-hour, annual) are achieved through simple averaging of sequential, hourly values. The EPA recommends that a full year of historical meteorological data be used with ISCST so that all potential seasonal variations are accounted for.

Source data required by ISCST are relative location, elevation, pollutant emission rate, stack height, stack diameter, stack gas exit velocity, and stack gas exit temperature for each emission point. ISCST can also accommodate area sources which may be used because emissions truly emanate on an area-wide basis, individual sources in the area are small or difficult to characterize, or combining point (individual) sources increases computational efficiency. Input data required for area sources are location (southwest corner), elevation, pollutant emission rate, area source length, and effective emission release height. The emission release height parameter for area sources essentially replaces the four stack parameters required for point sources, because those four parameters are used by the model to calculate effective plume height. The source elevation parameter was not a factor in the Williston Basin Study because uneven terrain was not accounted for (i.e., all elevations were set to zero).

ISCST model calculations are performed for all receptor locations specified by the user. Generally, the receptor grid generation facility of ISCST is deployed to saturate the region of concern with receptors. Cartesian or polar coordinate systems can be specified.

Finally, ISCST requires user selection of certain technical options which affect the treatment of plume rise and dispersion in the model simulation. Generally, these technical options are set to EPA-recommended values.

4.3.3 Source Data

As indicated in the methodology outline, each Study field was treated as a separate modeling problem, with separate sets of source input data, for the Ambient and PSD Class II SO_2 analyses. With the source grouping feature of the ISCST model, results for all four ambient and PSD Class II scenarios (i.e., existing ambient, future ambient, existing PSD Class II, future PSD Class II) were produced using one all-inclusive set of input data for each Study field. Still, however, more than one execution of the model was required for some Study fields because of the large number of receptors involved.

For each Study field, source data included nearby, potentially interactive sources as well as the treaters and flares within the subject field, itself. The modeling analyses addressed the following components of air quality impact:

1) Contribution of treaters and flares which lie within the subject-field boundaries,

2) Contribution of nearby treaters, flares, and other major significant SO_2 sources which lie outside the subject-field boundaries, but within a 50 km radius of the center of the subject field, and

3) Contribution of all natural SO_2 sources, and anthropogenic sources beyond 50 km from the center of the subject field.

The first two items, amounting to the contribution of all anthropogenic SO_2 sources within 50 km of the center of the subject field, were accounted for with dispersion modeling. The last item, amounting to the contribution of anthropogenic SO_2 sources beyond 50 km of the center of the subject field as well as the contribution of all natural SO_2 sources, was accounted for with a constant background SO_2 concentration which was added to dispersion modeling results (see Section 4.3.7). Therefore, ISCST model source input data was required for all lease-use treaters, active flares, and other significant SO_2 sources within 50 km of the center of the subject field. The 50 km cutoff for dispersion model application was consistent with the maximum EPA-recommended range of the ISCST model.

Source input data required by the ISCST model are summarized in Table 4-12. For standard (point) sources, stack location (cartesian or polar coordinate system), stack base elevation, pollutant emission rate, stack height, stack diameter, stack gas exit velocity, and stack gas exit temperature must be provided for each emission point. Because of the large number of sources involved in the Williston Basin Study, the area source feature of the ISCST model was used to combine nearby point sources into area sources, to the extent practical, to reduce model execution time. Required input data for area sources are location (southwest corner in cartesian or polar coordinates), elevation, pollutant emission rate (area-average), effective emission release height, and length of the designated area (area sources are constrained to be square).

TABLE 4-12
Source Input Data Required by ISCST*
(for each source)

Parameter	Units
Identification Number (5 digits)	
Source Type (0=stack, 2=area) (Part of I.D. Number)	
Pollutant Emission Rate	grams/sec (point source) grams/sec/m² (area source)
X coordinate of Stack	meters
Y coordinate of Stack	meters
Elevation at Stack Base	meters
Stack Height (emission height)	meters
Stack Exit Temperature**	Deg. Kelvin
Stack Exit Velocity**	meters/sec
Stack diameter**	meters
Width of Area Source***	meters

*Additional input information may be required if complex sources are involved or if building downwash is simulated (not applicable to WBS).
**Not required for area sources.
***Required only for area sources.

One additional input parameter required for both point and area sources is a source number. The source number is used to group sources in the ISCST model so that results for more than one source scenario can be achieved in a single model run. For the Williston Basin Study, the source number was coded to distinguish the source as being applicable to the existing ambient scenario, the future ambient scenario, the existing PSD Class II scenario, or the future PSD Class II scenario. Thus, a single set of source input data was used for each Study field, and results for all four scenarios were provided from each model execution.

For other types of sources, for simulation of structurally induced downwash, or for simulation of gravitational settling effects, the ISCST model requires additional source input parameters beyond what was described above and summarized in Table 4-12. However, none of these other source types or simulations are applicable to the Williston Basin Study.

The procedure used to prepare source input data for the WBS ambient and PSD Class II scenarios is illustrated in Figure 4-7. Specific aspects of the procedure are discussed in Sections 4.3.3.1 - 4.3.3.5.

4.3.3.1 Use of Measured Data for Study-Field Sources

The NDSDH concluded that the accuracy of source input data and subsequent quality of model predictions for existing SO_2 scenarios could be significantly improved if on-site measurements of treater and flare stack height and location were obtained for each of the Study fields. Originally, it was assumed that data for all source input parameters would be taken from the emission inventories developed in Section 4.2. But treater/flare stack height and location were frequently missing in the oil and gas data base from which the emissions inventory data were derived. While the substitutions of wellhead location for missing treater/flare location, constant 22 feet for missing treater stack height, and AAQS-achieving height for missing flare stack height are adequate for nearby sources (outside of subject field), the appropriateness of such substitutions for treaters and flares located within the subject field and associated receptor grid was regarded more tenuous. Substitution of wellhead location for missing treater/flare location in cases where the well was serviced by a central processing facility could lead to particularly erroneous results.

NDSDH personnel thus conducted field inspections to obtain measurements of stack height and location for lease-use treaters and active flares within the boundaries of each of the twelve Study fields. Observations were also made regarding the location and configuration of centralized processing facilities, if present. SO_2 emission rate and heat of combustion (for developing other required stack parameters) for Study-field treaters and flares were obtained from the emissions inventory for existing wells, as originally planned.

All model input parameters for nearby wells (outside of subject field), including location and stack height, were obtained from the emissions inventory, because it was not logistically possible to obtain on-site measurements for all of these wells. Given the typical distance of nearby wells from the receptors of concern, and the fact that many of these wells were grouped as area sources anyway, it was concluded that potential inaccuracies in treater/flare location and stack height for nearby wells would not significantly affect dispersion model results.

4.3.3.2 Derivation of Virtual Stack Parameters

The required source input parameters stack diameter, stack gas exit velocity, and stack gas exit temperature are not directly available from the emissions inventories for existing and future wells. As indicated earlier, however, virtual values for these three parameters can be derived from heat of

combustion, which is present in the inventories. The derived values are virtual in the sense that, though they are not physically meaningful, their use provides appropriate modeling results (plume rise). This point becomes clearer upon review of ISCST model equations.

The stack diameter, stack gas exit velocity, and stack gas exit temperature are used by the ISCST model to calculate plume rise. Plume rise equations in ISCST are based on work by Briggs[20,21]. To simulate plume rise, the model initially calculates the buoyancy flux parameter

$$F = \frac{gVD^2}{4}\left(\frac{T_s - T}{T_s}\right) \qquad (1)$$

where:

F = buoyancy flux parameter (m^4/sec^3)
g = acceleration of gravity (9.8 m/sec^2)
D = stack diameter (m)
V = stack gas exit velocity (m/sec)
T_s = stack gas exit temperature (°K)
T = ambient air temperature (°K)

All subsequent model calculations for plume rise are based on the buoyancy flux parameter.

Though this form is not used in the ISCST model, Briggs demonstrates that the buoyancy flux parameter can also be derived as

$$F = \frac{gQ}{\pi C_p \rho T} \qquad (2)$$

where:

Q = net sensible heat release from stack (calories/sec)
C_p = specific heat of air (calories/g°K)
ρ = density of air ($\mu g/m^3$)

Further, the net sensible heat release Q is related to the heat of combustion as follows:

$$Q = 0.75\ (H_c) \qquad (3)$$

where H_c = heat of combustion (calories/sec). Equation (3) reflects an empirical relationship suggested by Beychok[22] to account for heat loss resulting from outside air entrained into the stack plume.

Upon substitution of (3) into (2) and (2) into (1), one obtains

$$\frac{gVD^2}{4}\left(\frac{T_s - T}{T_s}\right) = \frac{0.75\ (H_c)\ g}{\pi C_p \rho T}$$

or

$$VD^2 = \frac{3H}{\pi C_p \rho T} \left(\frac{T}{T_s - T} \right) \qquad (4)$$

Thus, if values of V, D, and T_s are obtained to satisfy (4), the correct buoyancy flux will be calculated by (1), even if the values selected for V, D, and T_s are not physically realistic.

Equation (4) can be simplified by noting that π is a constant, and C_p, ρ, and T are essentially constants. C_p, ρ, and T can be treated as constants (i.e., selected for a typical ambient air temperature) because the buoyancy flux computed by (1) is not very sensitive to variations in T, given the significantly higher stack gas exit temperature T_s. For ambient air at 20°C,

$T = 293$ °K
$C_p = 0.24$ calories/g°K
$\rho = 1205$ µg/m³

and

$$VD^2 = \frac{3H}{\pi (0.24)(1205)(293)} \left(\frac{T}{T_s - 293} \right)$$

It is now apparent that V, D, and T_s can be solved simply in terms of the heat of combustion. If 1000°K is arbitrarily chosen for T_s,

$$VD^2 = (5.01 \times 10^{-5})\, H/\pi \qquad (5)$$

which is the relationship used by the NDSDH to calculate virtual values for stack diameter and exit velocity for the Williston Basin Study.

4.3.3.3 Source Data Preparation

To simplify the procedure, source input data preparation was grouped into the following components for each Study field.

1) Input data for existing Study-field sources.
2) Input data for existing nearby point sources.
3) Input data for existing nearby area sources.
4) Input data for future point sources (Study-field and nearby).
5) Input data for future nearby area sources.

These components are reflected in the source data preparation software system illustrated in Figure 4-7. Upon preparation, the individual components were concatenated into a single input file before model execution.

Input data preparation for existing Study-field sources (i.e., located within subject field boundaries) is discussed in Section 4.3.3.3.1. Input data preparation for existing nearby point and area sources (Components 2 and 3, above) is addressed in Section 4.3.3.3.2. Finally, Section 4.3.3.3.3 describes input data preparation for future Study-field sources, future nearby point sources, and future nearby area sources (Components 4 and 5, above).

4.3.3.3.1 Existing Study-Field Sources

As indicated previously, stack height and exact stack location for Study-field treaters/flares were obtained through on-site measurement, while SO_2 emission rate and heat of combustion (HOC) were obtained from the existing emissions inventory. Location of treaters and flares in the field was determined with respect to the wellhead location, because the wellhead location for each well was available from the emissions inventory (SIC oil and gas data base). A trigonometric approach was employed to determine the X and Y (east and north) offset of the treater/flare relative to the wellhead location. The distance between the treater/flare and wellhead was measured, and a bearing compass was used to determine the azimuth of the treater/flare with respect to the wellhead. The X and Y offsets were determined from these two measurements.

For some Study fields, certain circumstances mandated special considerations in the preparation of model input data from on-site measurements. In some instances, the well installation was abandoned and partially or totally dismantled subsequent to the time frame of the Williston Basin Study (i.e., November 1987 - March 1988). In order not to bias Study results, however, all producing wells in the inventory clearly had to be included in the model input file. The following procedure was therefore used in cases of well abandonment:

1) If the treater and flare were still present, or if there was enough evidence to establish their locations, the trigonometric method described above was used to establish exact treater/flare location for model input. If no evidence was present regarding former treater/flare location, the treater was located at the wellhead coordinates, and the flare was positioned 120 feet away from the treater in a random direction.

2) If the treater stack was no longer present, a stack height of 22 feet was assumed. If the flare stack was no longer present, the value assigned depended on the characteristics of other flare stacks in the same field. For the Stanley, Charlson, and Little Knife fields, flare stack heights tended to be significant; therefore, the field-average flare stack height was assigned for abandoned installations. All other Study fields, however, had primarily pit flares with very short stacks. A flare height of 1 foot was assigned for abandoned installations in these fields.

The 120 foot separation distance assumed for treaters and flares at abandoned sites is consistent with Federal spacing requirements, and is consistent with the treater-flare separation distance assumed for future well installations (Section 4.2.3.3). The use of a treater stack height of 22 ft is consistent with the industry-average value substituted for missing treater height while creating the existing emissions inventory, and the value assigned for all treaters when creating the future emissions inventory. The use of a variable stack height for abandoned flare situations is consistent with the determination, in the creation of both existing and future emissions inventories, that flare heights are typically too inconsistent to be represented by a constant substitution value.

The other circumstance which required special considerations in the preparation of model input data from on-site measurements was the presence of centralized processing facilities (centralized treater(s)/flare servicing more than one well) in some Study fields. In these cases, treater/flare heat of combustion was affected as well as stack height and stack location. The following procedure was used if a centralized processing facility was present:

1) Regardless of the number of wells serviced, centralized processing facilities generally included only one flare, and there was not necessarily a one-to-one correspondence between the number

TABLE 4-13
Source Input Data for Other Significant Sources

Source	PSD*	UTM Coordinates (km)*** East	North	SO_2 Emission (g/sec)	Stack Height (m)	Stack Diam. (m)	Exit Temp. (°K)	Exit Vel. (m/sec)
Enron Gas Plant	X	609.0	5294.0	17.6	61.0	1.2	477	10.2
Little Knife Gas Plant	X	643.8	5239.7	53.8	59.5	1.8	870	10.0
McKenzie County Gas Plant	X	575.4	5271.1	34.4	65.0	1.0	950	19.1
Koch (Perry Pet.) Gas Plant	X	570.6	5279.8	25.0	54.9	0.1**	1000**	99.4**
ANR (Shell Oil) Gas Plant	X	569.6	5280.3	44.8	61.0	0.2**	1000**	56.2**
Teddy Roosevelt Gas Plant	X	634.2	5220.1	28.4	30.5	1.1	866	15.0
Tioga Gas Plant	X	651.1	5362.6	135.3	30.5	1.7	782	7.7
Watford City High School	X	628.9	5295.4	1.9	13.9	0.4	440	19.5

* PSD here implies PSD-increment-consuming.
** Virtual value for this parameter was developed to accomodate flare stack in conventional models.
***All sources are located in UTM Zone 13.

assigned for these sources included a code digit to indicate whether or not the source is PSD-increment-consuming.

The output from Steps 5, 6, and 7, above, reflected complete ISCST model input for existing nearby sources.

Maps showing the configuration of existing nearby point and area sources for each Study field are included in Appendix B. An example of one of these maps was included in this Section as Figure 4-10. Note that these maps use the wellhead location to denote the location of corresponding treater and flare. Appendix B also includes a listing of all ISCST model input data for each Study field, including source data.

4.3.3.3.3 Future Sources

To complete model input data requirements, input data were lastly prepared for foreseeable-future treaters and flares. All future source input data were derived from the emissions inventory for future sources. Therefore, future treaters and flares located within the Study-field boundaries were treated the same as future nearby treaters and flares for purposes of preparing model input data.

To improve model computational efficiency, future point sources (treaters and flares) were grouped together as area sources whenever possible. Separate model input files were thus prepared for future point sources and future area sources, as depicted in Figure 4-7.

The procedure used to develop model input data for future sources is described below.

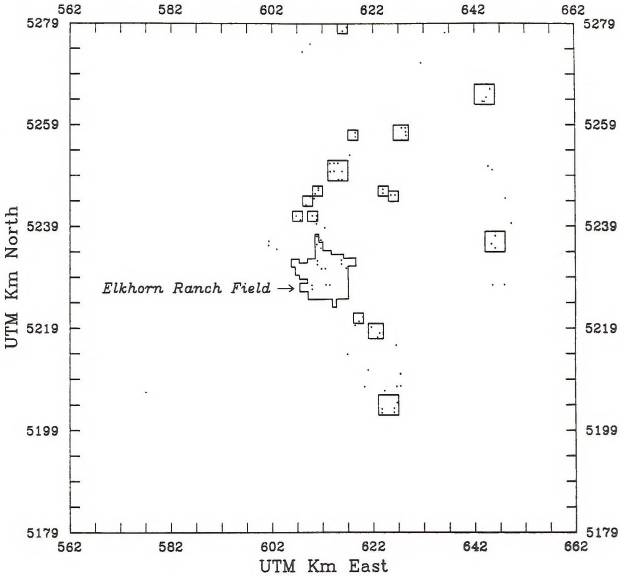
1) Using the large-scale maps created for area source determination (Section 4.3.3.3.2, Step 1), a subjective determination was made regarding the appropriate location and size of future area sources (so that they could be more easily distinguished, future well locations were plotted in a different color on the maps). To be of benefit in terms of computational efficiency, it was concluded that area sources must contain at least three point sources (future treaters or flares with SO_2 emissions 0), which suggested a minimum size for future area sources of 2 km on a side.

   Because use of area sources tends to smooth out details in the distribution of modeled downwind concentrations, it is desirable to limit the size of area sources near the receptor field. Accordingly, future area source size was generally limited to 2 km near the subject field, gradually increasing with distance such that the largest area sources were located at the maximum distance (near 50 km) from the center of the subject field. Area sources were not used for treaters and flares within subject field boundaries. Again, this type of area source distribution was consistent with the goal of increasing computational efficiency, while minimizing impact on overall modeling results.

   An example of future area-source configuration for the Elkhorn Ranch Field is shown in Figure 4-12. The Figure reflects a smaller version of the maps used by the NDSDH. It is apparent from Figure 4-12 that future area sources tend to be smaller nearer the subject field boundary, and that future area sources are only placed where future treater/flare grouping and density renders it practical.

   The task of mapping out area sources for future treaters and flares is depicted in Figure 4-9.

Figure 4-12
Elkhorn Ranch Field
Locations of Future SO_2 Point and Area Sources



2) A computer file was created of all mapped-out future area sources. Included in the file were the UTM coordinates of the southwest corner, and length, for each area source. As shown in Figures 4-9 and 4-7, this computer file constituted output from the mapping procedure for future sources, and input to program AREAF.

3) Future treaters and flares not grouped with any area source were treated as conventional point sources. A computer file was created of all remaining future wells (those having a treater or flare with SO_2 emissions 0 and which were not included in any area source). The only information included in the file was an identification number for each remaining future well. As shown in Figures 4-9 and 4-7, this computer file constituted output from the mapping procedure for future sources, and input to program POINTF.

4) Final preparation of the model input file for future area sources was accomplished with the development and execution of Fortran program AREAF. Location and size of each area source were obtained from the AREAF input file established in Step 2, above. Information for developing area-average emission rate and effective release height was obtained from the emissions inventory for future wells, which is noted as one of the program AREAF inputs in Figure 4-7. Program AREAF developed the area-average emission rate by summing the SO_2 emissions of all future treaters and flares within the designated area source, then dividing by its area. The effective release height was calculated as the sum of the weighted-average stack height, and a plume rise based on the weighted-average heat of combustion and worst-case meteorological conditions. The specific procedure for calculating effective release height for future area sources was the same as that described for existing area sources in Section 4.3.3.3.2, Step 5. Program AREAF also assigned a sequence number for each future area source and assembled all area source input data into an ISCST-compatible input file.

5) Final preparation of the model input file for future point sources (treaters and flares) was accomplished with the development and execution of Fortran program POINTF. Using the file of well identification numbers generated in Step 3, above, the emissions inventory for future wells was searched by program POINTF to determine the location, SO_2 emission rate, stack height, and heat of combustion for each designated treater and flare. Virtual values for stack diameter, stack gas exit velocity, and stack gas exit temperature were subsequently determined from the heat of combustion using equation (5) (from Section 4.3.3.2). Lastly, program POINTF assigned a sequence (modified identification) number for each point source and assembled all point source input data into an ISCST-compatible input file. The sequence number included a code digit to indicate whether the point source reflected a treater or flare.

The output from Steps 4 and 5, above, reflected complete ISCST model input for future sources.

Maps showing the configuration of future point and area sources for each Study field are included in Appendix B. An example of one of these maps was included in this Section as Figure 4-12. Note that wellhead locations are used to represent treaters and flares on these maps. Appendix B also includes a listing of all ISCST model input data for each Study field, including source data.

4.3.4 Receptor Data

The necessary configuration and density of the dispersion model receptor grid are dependent on the characteristics of the modeling problem. Generally, greater receptor density is required for problems

involving short stacks than for problems involving tall stacks or highly buoyant plumes. The effluent plume from a short stack will tend to "impact" the ground closer to the stack, with correspondingly less opportunity for dispersion. Thus, ground-level concentration gradients will be stronger in the vicinity of short stacks, and denser receptor spacing will be necessary to ascertain the maximum pollutant concentration (usually the goal of air quality modeling analyses).

The Williston Basin Study involved sources with relatively short stacks. Treater stack heights did not exceed 40 feet. Flare stacks seldom exceeded 50 feet, and were typically closer to ground level. The presence of such short stacks suggested that a relatively dense receptor grid would be necessary for modeling the Study fields. The necessity of relatively dense receptor spacing was also apparent from past NDSDH experience in modeling oil and gas well installations.

For the Williston Basin Study fields, it was decided that the areal extent of the receptor grid would be defined by a rectangle which is somewhat larger than necessary to contain the entire subject field. This decision was based on the recognition that the ground-level impact of SO_2 sources within the Study field, though relatively localized because of short stacks, could still spread beyond the boundaries of the field. The use of a rectangular, cartesian receptor grid also accommodated the graphical procedures (contour plots) which were incorporated to present and interpret modeling results (Section 5).

Because of the relatively large size of some of the Study fields, and the prohibitive computer execution time which could potentially be required, it was concluded that indiscriminant use of densely spaced receptors over the entire grid area for each field was not practical. A compromise protocol was therefore adopted involving judicious use of three different receptor spacing schemes, as described below:

1) <u>Initial receptors</u>

   For the initial model execution for each field, receptor spacing was set at 200 meters (UTM coordinate system), and receptors were only placed in areas where sources (treaters and flares) existed (i.e., receptors were not included in inactive parts of the grid area). The receptor spacing of 200 meters was considered marginally adequate.

2) <u>Refined receptors</u>

   For local areas where the initial model execution revealed "hot spots" with relatively high concentrations, the model was rerun with denser receptor spacing. Generally, refined receptor spacing was set at 100 meters. Refined receptor spacing was set at 50 meters, however, if the initial model run revealed particularly strong concentration gradients.

3) <u>Fill-in receptors</u>

   One additional model run was made for each field using economically placed receptors to "fill-in" those parts of the grid area where receptors had not been previously placed (in initial or refined runs). The primary purpose of the fill-in receptors was to accommodate contour plotting of the entire grid area. Spacing for fill-in receptors was generally 1000 meters.

Using this approach, receptor density was still maximized where it was most critical, but significant economy was achieved in computer time because of the overall reduction in receptor numbers.

The complete receptor grid used for the Stanley Field is presented in Figure 4-14 as an example to illustrate the use of the three receptor-spacing schemes. Each receptor is represented by a dot in the figure (through not visible in the figure, receptors are present along the map boundary). Figure 4-14 is preceded by Figure 4-13, which shows source locations for the Stanley Field. The three different receptor-spacing schemes are evident in Figure 4-14. It is also evident that the initial 200-meter receptors are only placed in the vicinity of sources. The significantly less dense fill-in receptors cover those areas where no sources are present. Lastly, it is apparent from Figure 4-14 that refined receptors are used only in relatively small subregions of the initial receptor (200-meter) block.

Maps showing the complete receptor grid used for each Study field are included in Appendix B. Though not visible in the figures, receptors are also present along the map boundaries.

It should be noted that the same receptor grid was used for all four scenarios (existing ambient, future ambient, existing PSD Class II, future PSD Class II) for a given Study field. When locating initial 200-meter receptor blocks, therefore, the locations of both existing and future sources were taken into account.

Finally, it should be noted that a limited number of receptors for some Study fields may lie within well-site property areas. According to EPA and NDSDH modeling policy, air quality levels within source property boundaries need not be considered when determining compliance with AAQS or PSD Class II increments, as long as the property area has limited access, i.e., is fenced or closed off in some other way. Though the majority of well sites in the Study area do not have fences, a very limited number of receptors may lie within well-site property areas that do. As such, predicted concentrations at those receptors should have been disallowed when interpreting model results, but weren't because it would have been too cumbersome to identify well sites which are truly limited access. Inclusion of predictions for the very limited number of receptors which may have been located within limited-access well-site property areas, however, will have little significance in the context of overall modeling results.

4.3.5 Meteorological Data

The ISCST model simulates dispersion and transport of pollutants using actual historical meteorological data. The model thus requires input of representative hourly meteorological observations, preferably for at least one year of record. Meteorological data required include sequential hourly values for wind speed, wind direction, mixing height, stability class, and ambient temperature. Wind direction is used by the ISCST model to control the direction of plume transport. Wind speed controls the dispersion of effluent material along the length of the plume, while stability class (a measure of atmospheric turbulence) determines the crosswind rate of dispersion. Mixing height defines the available atmospheric boundary layer through which mixing of the plume material can occur, and ambient temperature is used in plume rise calculations.

To achieve realistic results, meteorological data used with the ISCST model must be representative of dispersion and transport conditions in the Study area. For modeling analyses which are conducted on a local basis, representativeness is best achieved if meteorological data are collected on-site. Because of the regional scale of the Williston Basin Study, and the spatial consistency of meteorological conditions in western North Dakota, however, it was concluded that National Weather Service (NWS) data from Williston would be representative of the entire Study area. The use of a single meteorological data set also afforded consistent interpretation of modeling results for all twelve Study fields. Surface observations (wind speed and direction, stability class, ambient temperature) from Williston were coupled with

Figure 4-13
Stanley Field
Locations of Study-Field SO_2 Sources

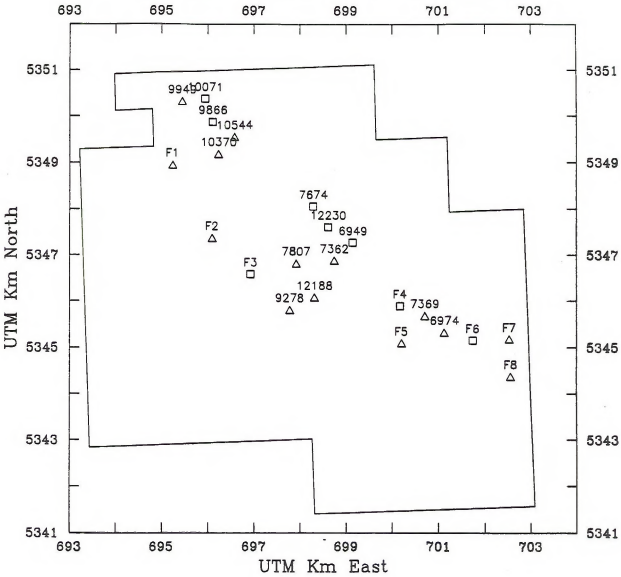
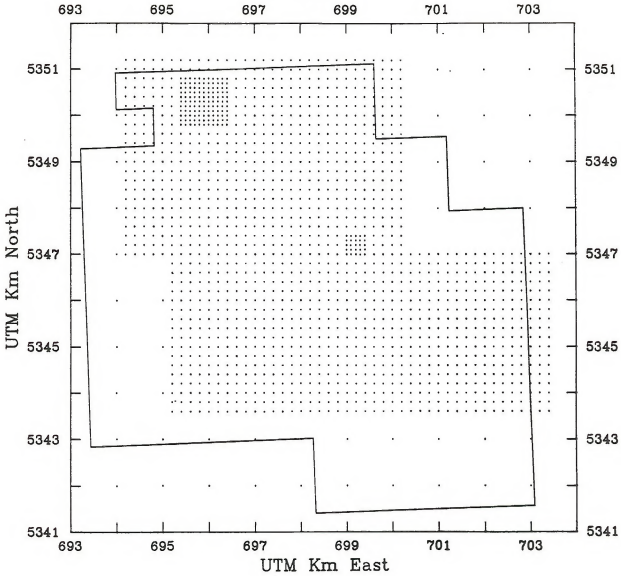


Figure 4-14
Stanley Field
ISCST Receptor Locations



Bismarck NWS mixing heights, as upper-air data are not available from Williston. Use of NWS meteorological data is a common practice in regulatory modeling problems and, because upper-air data is not collected at all NWS stations, it is not unusual to couple surface data with mixing heights from a different station.

At least one year of meteorological data is normally used with the ISCST model. The use of at least one year of data allows all seasonal variations in meteorological patterns to be accounted for, and allows the model to compute an annual average pollutant concentration (in addition to shorter-term averages). Modeling for one year of meteorological data also affords a direct comparison of model results with air quality standards, which are usually stated in terms of exceedances allowed per year. The use of more than one year of meteorology is desirable so that yearly variations can be accounted for as well as seasonal variations.

Given the anticipated computer resource demands of the Williston Basin Study, it was concluded impractical to use more than one year of Williston/Bismarck data with the ISCST model. However, the year of data selected (1983) was investigated for representativeness with respect to other years of available meteorological data. At the outset of the Williston Basin Study, the NDSDH meteorological data base included Williston/Bismarck data sets for 1971 through 1975, 1982, and 1983. The 1983 data were initially selected for the Study because they reflected the most recent data set.

To facilitate investigation of representativeness of the 1983 data, Williston NWS wind roses were prepared for 1975, 1982, and 1983 (corresponding to the most recent three years of available meteorological data), as shown in Figures 4-15, 4-16, and 4-17, respectively. Based on a comparison of the Figures, it is apparent that the pattern of wind speed and direction is very similar for all three years. All three roses exhibit peaks in northerly, southeasterly, and south-southwesterly wind directions. All three roses exhibit a tendency for more westerly winds, overall, than easterly winds. Further, the distribution of wind speeds appears very similar for all three years.

To more directly evaluate representativeness of the 1983 meteorological data for the Williston Basin Study, the ISCST model was run using actual existing scenario input data for one of the Study fields (Lone Butte). Input data were developed as described elsewhere in this section. Separate ISCST executions were conducted for 1975, 1982, and 1983 Williston/Bismarck meteorological data. Except for meteorology, all other input data remained constant for the three runs.

Results of the ISCST model executions for the Lone Butte Field are shown in Table 4-14. The ten highest predicted SO_2 concentrations are listed for 1-hour, 3-hour, and 24-hour averaging periods, without regard for temporal or spatial duplication. The results of Table 4-14 indicate that the three years of meteorology produced very similar predictions for highest concentrations, and that model results were not particularly sensitive to the actual meteorological data used. These results were anticipated not only because of the similarity in wind roses for the three years of meteorological data reviewed, but also because the fairly even spacing of oil and gas facilities renders modeling results less sensitive to changes in meteorological conditions, particularly changes in wind direction.

Based on the comparison of wind roses, based on the ISCST test results for the Lone Butte Field, and considering the similarity of source characteristics in the Lone Butte Field to those of the other Study fields, it was concluded that the 1983 Williston/Bismarck data set was representative of recent meteorological conditions in the Study area. Therefore, the 1983 Williston surface/Bismarck upper-air data were utilized for the Williston Basin Study ambient and PSD Class II (existing and future) scenario analyses.

Figure 4-15
Williston NWS - 1975

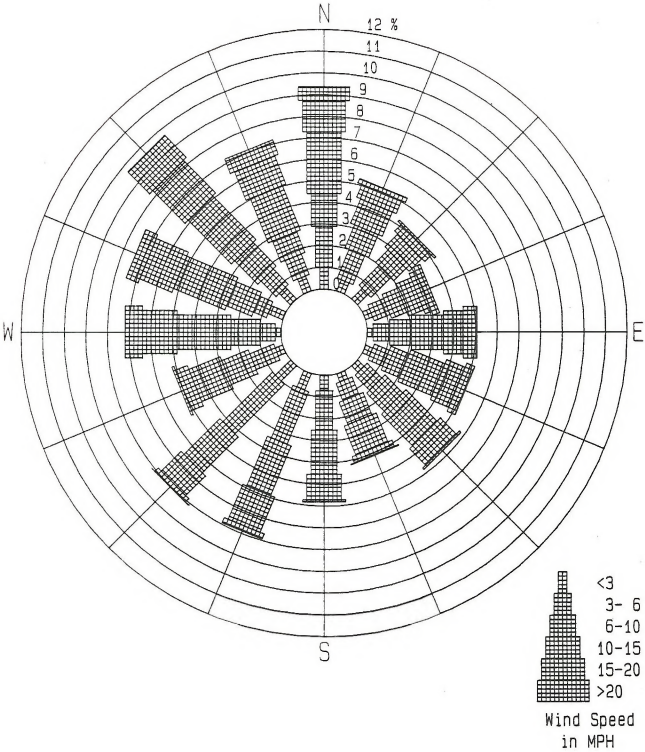


Figure 4-16
Williston NWS - 1982

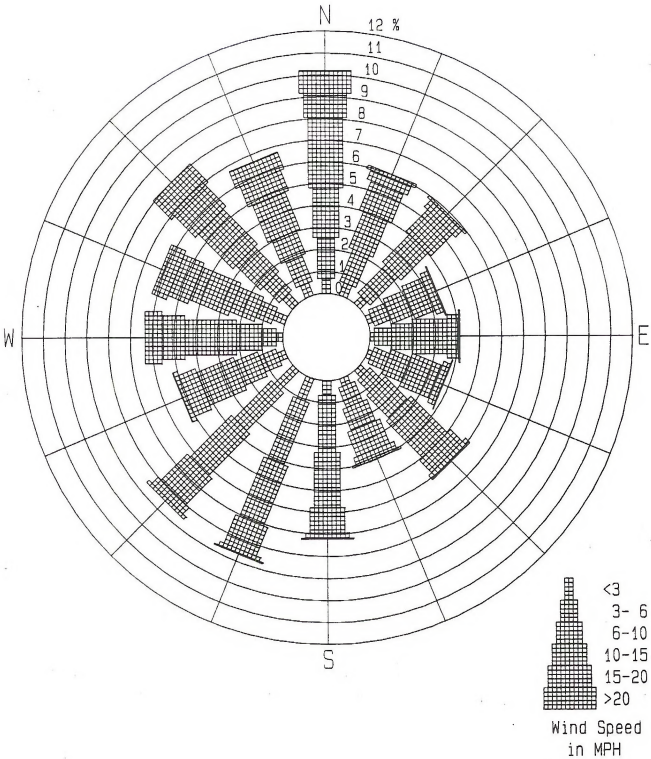


Figure 4-17
Williston NWS - 1983

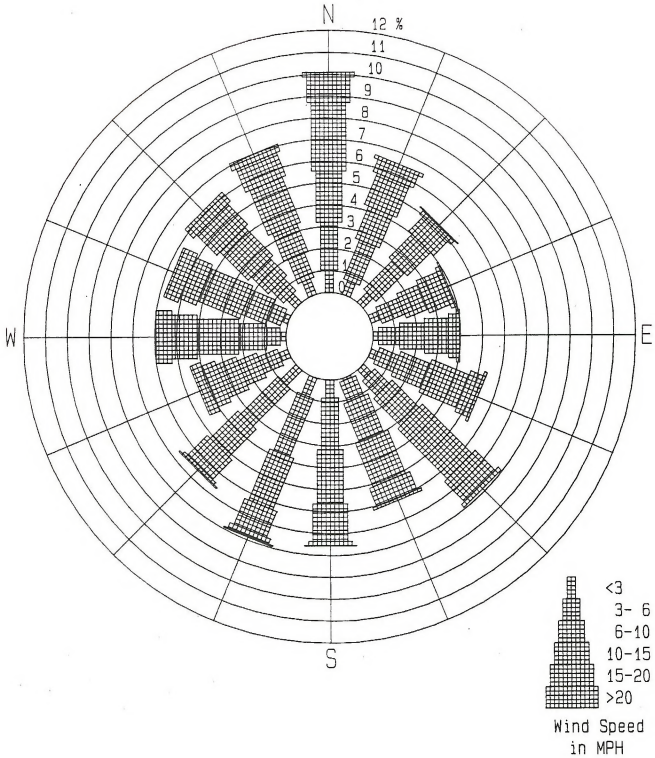


TABLE 4-14
Lone Butte Field: Existing Ambient Scenario
Ten Highest Predicted SO_2 Concentrations ($\mu g/m^3$)

1-Hour Average

1975 Meteorology	1982 Meteorology	1983 Meteorology
1758	1293	1302
1664	1283	1277
1640	1271	1272
1329	1268	1272
1297	1267	1270
1295	1263	1268
1277	1257	1265
1276	1257	1264
1269	1256	1257
1260	1253	1253

3-Hour Average

1975 Meteorology	1982 Meteorology	1983 Meteorology
1181	1247	1191
1144	1029	967
955	955	947
952	942	922
873	908	889
863	896	864
859	872	864
855	865	860
847	858	851
845	856	842

24-Hour Average

1975 Meteorology	1982 Meteorology	1983 Meteorology
425	494	421
421	372	383
415	365	374
406	357	368
343	341	364
342	332	363
329	309	353
314	308	342
310	307	328
306	305	324

One other option which was earlier considered regarding meteorology was to use data for the same period on which emissions information was based in the emissions inventory for existing wells, i.e., November 1987 through March 1988. The obvious advantage would be that meteorology and emissions data would be concurrent, theoretically resulting in more realistic model predictions for existing scenarios. This option, however, suffered major drawbacks, including:

1) Properly coded meteorological data (National Climatic Center) for Williston and Bismarck NWS stations were not yet available for 1988.

2) Use of less than one full year of meteorological data would render a comparison of modeling results with air quality standards difficult.

3) Use of November 1987 through March 1988 data would not have been meaningful for modeling future scenarios, and it had previously been concluded that, for economic reasons, existing and future scenarios would have to be included as separate source groups in one model execution.

Further, it has just been shown that the 1983 meteorological data selected is representative of recent meteorological conditions in the Study area. For these reasons, the option of using November 1987 through March 1988 meteorological data was not further considered.

4.3.6 Model Technical Options

The last component of model input preparation was the selection of technical options. The ISCST model allows the user to control various aspects of the simulation through selection of these input parameters. These technical input options, and usage for the Williston Basin Study, are summarized in Table 4-15.

TABLE 4-15
ISCST Technical Options

Option	Williston Basin Study
Rural environment/Urban environment	Rural
Cartesian coordinate system/Polar coordinate system	Cartesian
Gradual plume rise/Final plume rise	Gradual
Stack-tip downwash/No stack-tip downwash	No stack-tip downwash
Buoyancy induced dispersion/ No buoyancy induced dispersion	Buoyancy induced dispersion
Calm wind adjustments/No calm wind adjustments	Calm wind adjustments
Pollutant decay/No pollutant decay	No pollutant decay
Terrain ht. variations considered/ Terrain ht. variations not considered	Not considered
Wind-speed profile exponents (Stability Classes 1-6)	.07,.07,.10,.15,.35,.55
Vertical pot. temp. gradients (Stability Classes 1-6)	.00,.00,.00.,00,.02,.035

It is beyond the scope of this report to discuss the ISCST model technical options in detail. It suffices to say that, with the exception of stack-tip downwash and gradual plume rise, technical options were set according to EPA guidance for use of the model in regulatory analyses[13,14]. Stack-tip downwash, an adjustment to plume rise, was not deployed because its calculation depends on the stack gas exit velocity. The model input exit velocity used for treaters and flares in the Williston Basin Study, however, is a virtual value computed with Equation (5), and not physically meaningful.

Though the EPA endorses the use of final plume rise (plume immediately attains and maintains final height), gradual plume rise was deployed for the Williston Basin Study. The EPA guidance assumes the modeling analysis involves generally tall stacks, where the distance between the ground and plume centerline, near the stack, is not a significant factor in the simulation. Because of the very low stack heights involved in the Williston Basin Study, particularly for some flares, however, it was concluded that the gradual plume rise option would more realistically simulate the spatial relationship between receptors and plume centerline in the vicinity of treater and flare stacks.

4.3.7 Background Concentrations

A background concentration was added to dispersion model results for existing and future ambient scenarios to account for the contribution of natural SO_2 sources, and the contribution of anthropogenic SO_2 sources beyond 50 km from the center of the subject field. A background concentration is used to reflect the contribution of these sources because it would simply not be practical to include all of them directly in the model execution. Further, ISCST model predictions become increasingly tenuous for sources located more than 50 km away from the receptors of concern.

Background SO_2 concentrations used for the Williston Basin Study were derived from monitoring data collected at the NDSDH's Dunn Center monitoring site. Data from Dunn Center were used because the site is relatively distant from large oil fields and other major SO_2 sources, and is therefore representative of the contribution of distant and natural SO_2 sources to Study-field receptors (see Figure 3-3).

To be consistent with the production period selected for developing the oil and gas well emissions inventory (November 1987-March 1988), Dunn Center data for 1987 and 1988 were used for developing SO_2 background concentrations. A statistical frequency analysis was applied to the Dunn Center SO_2 data for these two years. Based on this analysis, background concentrations which reflected generally the 99th percentile SO_2 concentration were selected for each averaging period. These background concentrations are shown in Table 4-16. Use of the 99th percentile value is consistent with NDSDH policy regarding background concentrations for air quality modeling analyses. Previous NDSDH experience has shown that the 99th percentile concentration should conservatively account for nonmodeled SO_2 sources.

TABLE 4-16
SO_2 Background Concentrations ($\mu g/m^3$)

Averaging Period	Background
1-hour	13
3-hour	11
24-hour	9
Annual	3

4.3.8 Model Execution

For each Study field, the ISCST model was executed with source data, receptor data, meteorological data, and technical options as described in Sections 4.3.3 through 4.3.6. As shown in Figure 4-7, source input data files for existing Study-field sources, existing nearby sources, and all future sources were combined with receptor data and technical option selections to form the requisite ISCST input file. The complete ISCST input file listings for each Study field are included in Appendix B.

Using the source grouping feature of the ISCST model, results for all four ambient and PSD Class II SO_2 scenarios (i.e., existing ambient, future ambient, existing PSD Class II, future PSD Class II) were produced using one all-inclusive set of input data for each Study field. The sequence number (required input for each source) was used to designate for which scenario a source's contribution was applicable.

Because of the large number of sources and receptors involved, model execution for some Study fields was separated into more than one computer run using different receptor groups. As indicated previously (Section 4.3.4), the model was executed first for the initial (200-meter) receptors, then for the refined receptors. If necessary, the model was also executed for fill-in receptors. A large number of computer runs and a substantial amount of computer time were required to complete the ambient and PSD Class II analyses for all twelve Study fields.

4.4 Modeling PSD Class I SO_2 Scenario

This section describes the dispersion modeling procedure which was applied to predict maximum potential SO_2 concentrations for the PSD Class I scenario (i.e., maximum Class I increment consumption). As shown in Figure 3-1, four PSD Class I areas are located in the vicinity of the Williston Basin Study area. However, none of the twelve Study fields overlays any part of these four Class I areas. Therefore, unlike the PSD Class II analyses where model receptors were located within each of the Study fields, receptors for the PSD Class I scenario were located only in the four Class I areas, and separate Class I analyses were conducted on the basis of the four Class I areas rather than the twelve Study fields. The purpose of the PSD Class I analysis was thus to determine the SO_2 impact of nearby oil and gas fields on Class I receptors. PSD Class I is not applicable to H_2S.

Because of greater concern for air quality in Class I areas, and because allowable increments for PSD Class I areas are consequently considerably lower than for PSD Class II areas (see Table 2-2), proper quantification of the impact of sources farther than 50 km away, particularly large sources, becomes more critical for the PSD Class I analysis than for the Class II analysis. For regulatory Class I analyses, therefore, the NDSDH models all PSD sources located within 250 km of the subject Class I area. Because of the limitations of steady-state models (such as ISCST) with respect to such distances, the NDSDH utilizes a dynamic, long-range model (MSPUFF) for its regulatory Class I analyses.

One limitation associated with previous Class I analyses conducted by the NDSDH is that the additive impact of PSD-increment-consuming oil and gas production facilities has not been accounted for. This is because a complete emissions inventory for oil and gas sources was not available. Even if a proper emissions inventory had been available, the cost of running the long-range model with all PSD-increment-consuming oil and gas sources included would likely have been prohibitive.

Clearly, it was desirable to address the impact of PSD-increment-consuming oil and gas production facilities in the Williston Basin Study Class I analysis. But even with the cost advantages of the desktop

computer used for the ambient and PSD Class II SO_2 scenarios, modeling all PSD-increment-consuming oil and gas sources with the long-range model would have been prohibitive in terms of execution time. Therefore, a hybrid modeling approach was adopted for the Williston Basin Study Class I analysis. As before, major PSD-increment-consuming sources located within 250 km of subject Class I areas, other than those associated with oil and gas production, were modeled using the long-range model. PSD-increment-consuming oil and gas sources, located within 50 km of subject Class I areas, were modeled using the ISCST model and the methodology that was used for the ambient and PSD Class II SO_2 scenarios. The results of both models were then added, on the basis of concurrent averaging blocks, to determine final Class I increment consumption.

With this hybrid procedure, the impact of PSD-increment-consuming oil and gas sources beyond 50 km from the center of the subject Class I area were not accounted for. One option considered was to assume that the background concentration utilized in the ambient SO_2 scenario would reflect also the contribution of PSD-increment-consuming sources at distances greater than 50 km from Class I areas. However, the background concentrations were judged not to be very representative of this component because the impact of many non-PSD-increment-consuming sources would also be included. In any event, it was concluded that the impact from PSD-increment-consuming oil and gas sources located more than 50 km from Class I receptors would not be significant.

The modeling methodology employed for the WBS PSD Class I scenario was based on recommendations in the EPA Guideline on Air Quality Models (Revised)[13,14] and in the North Dakota Guideline for Air Quality Modeling Analyses[15]. The methodology is outlined in Section 4.4.1, and is described in detail in Sections 4.4.2-4.4.7. Class I modeling procedure is also depicted in the flow charts of Figures 4-18 and 4-19.

4.4.1 Methodology Outline

A. Dispersion Model

1) The MSPUFF[23] long-range model was applied for major PSD-increment-consuming sources, other than oil and gas facilities, located within 250 km of the center of the subject Class I area.

2) The EPA ISCST steady-state model was applied for PSD-increment-consuming oil and gas sources located within 50 km of the center of the subject Class I area.

3) Both MSPUFF and ISCST models require source data (location, pollutant emission rate, stack height, stack diameter, stack gas exit velocity, and stack gas exit temperature for each source), receptor data, representative meteorological data, and user selection of certain technical options before they can be executed. Meteorological data requirements for MSPUFF are considerably more complex than for ISCST.

B. Source Data

1) Class I areas addressed for the Williston Basin Study include:

FIGURE 4-18

PSD CLASS I SOURCE INPUT

PREPARATION SYSTEM

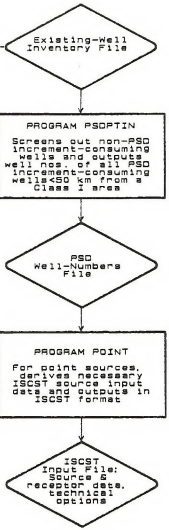
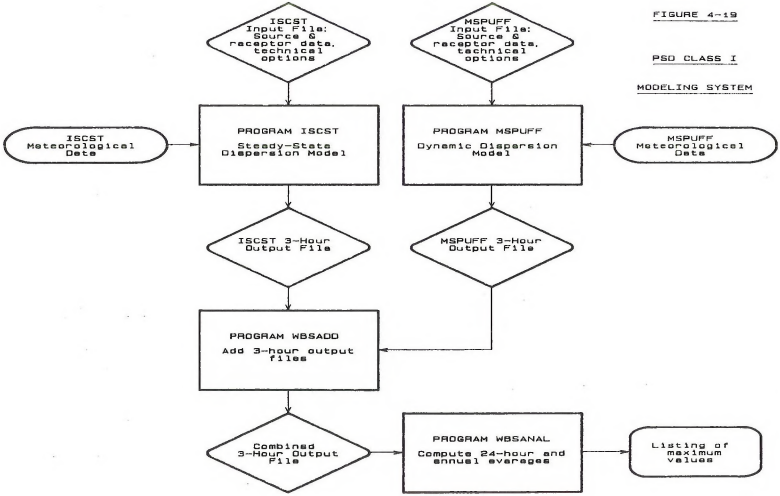


FIGURE 4-19

PSD CLASS I

MODELING SYSTEM



Theodore Roosevelt National Park - North Unit
Theodore Roosevelt National Park - South Unit
Theodore Roosevelt National Park - Elkhorn Ranch
Lostwood National Wilderness Area

Each of these Class I areas was treated as a separate modeling problem, with separate sets of source input data.

2) For each Class I area, source data included all PSD-increment-consuming oil and gas SO_2 sources (treaters and flares) located within 50 km of the center of the Class I area, and all major PSD-increment-consuming SO_2 sources (other than oil and gas sources) located within 250 km of the center of the Class I area. (The contribution of oil and gas sources beyond 50 km was concluded to be insignificant.)

3) The ISCST model was used to determine the contribution of PSD-increment-consuming oil and gas SO_2 sources, located within 50 km, to Class I area receptors.

4) The MSPUFF model was used to determine the contribution of major PSD-increment-consuming sources, located within 250 km, to Class I area receptors.

5) The contribution of sources modeled using the ISCST model and the contribution of sources modeled using the MSPUFF model were added, on the basis of concurrent averaging blocks, to determine final increment consumption at Class I receptors.

6) The location, SO_2 emission rate, and stack height for all oil and gas sources (treaters and flares) was taken from the emissions inventory developed in Section 4.2.

7) Using the procedure described in the North Dakota Guideline for Air Quality Modeling Analyses, virtual values for stack diameter, stack gas exit velocity, and stack gas exit temperature for all oil and gas sources were derived from the emissions inventory heat of combustion as developed in Section 4.2.

8) All necessary source input data for other major PSD-increment-consuming SO_2 sources were taken from the NDSDH emissions inventory of such sources.

C. Receptor Data

1) For the Williston Basin Study, the standard set of Class I area receptors established by the NDSDH for regulatory PSD Class I analyses was utilized.

2) Uneven terrain was not accounted for, i.e., elevation for all sources and receptors will be set to zero.

D. Meteorological Data

1) Concurrent meteorological data sets for one year were used with the ISCST and MSPUFF models.

2) The 1983 Williston surface/Bismarck upper-air NWS meteorological data set was used with the ISCST model.

3) The NDSDH's standard MSPUFF gridded meteorological input file for 1983, reflecting a composite of several NWS stations, was used with the MSPUFF model.

E. Model Technical Options

1) With the exception of treatment of stack-tip downwash and gradual plume rise, ISCST technical options were deployed according to standard EPA guidance.

2) ISCST stack-tip downwash was not deployed because a virtual (not physically meaningful) exit velocity was used for treaters and flares.

3) ISCST gradual plume rise was deployed because it is technically more appropriate (than final rise) given the low-level emissions of treaters and flares.

4) MSPUFF technical options were deployed according to guidance in the North Dakota Guideline for Air Quality Modeling Analyses, which has been reviewed and approved by EPA.

Modeling methodology is discussed in detail in Sections 4.4.2-4.4.7.

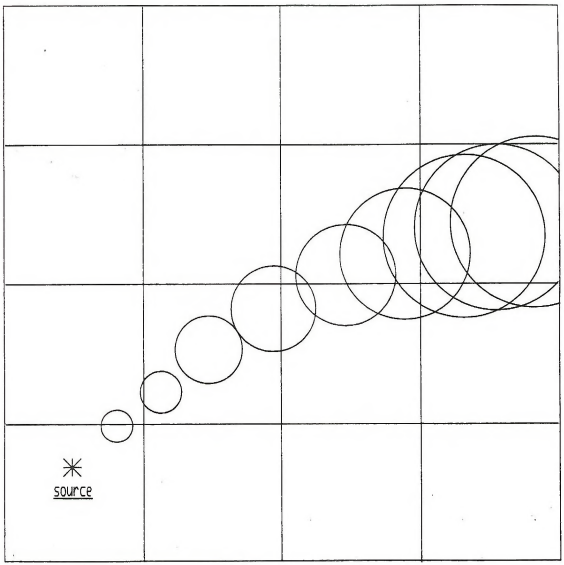
4.4.2 Model Selection

The hybrid modeling approach adopted for the WBS PSD Class I scenario essentially determined which models would be utilized. To maintain consistency with modeling analyses for the ambient and PSD Class II scenarios, ISCST was the clear choice for addressing PSD-increment-consuming oil and gas sources within 50 km of the center of subject Class I areas. Treatment of major PSD-increment-consuming sources (other than oil and gas sources) within 250 km of subject Class I areas, because of the large spatial scale, required a dynamic, long-range model. The only long-range model which has been approved by EPA for regulatory use in North Dakota, and the only model which has been applied by the NDSDH to long-range PSD Class I problems, is MSPUFF. Therefore, ISCST was applied for oil and gas sources within 50 km, and MSPUFF was applied for other major sources within 250 km, of the center of subject Class I areas.

The ISCST model is described in Section 4.3.2.

MSPUFF is a long-range variable-trajectory gaussian puff model. It differs from steady-state models, such as ISCST, in that it simulates advection and dispersion using a spatially and temporally varying horizontal wind field. This allows a more realistic treatment when greater distances are involved. MSPUFF simulates the plume from a continuous point source by superposing discrete puffs. Each puff is advected in a lagrangian sense—its time history is independent of preceding or succeeding puffs. The dimensions of an individual puff are proportional to its travel distance (or travel time). Receptor concentrations are obtained by adding the contributions of each puff which overlays the receptor location. The representation of a continuous plume by the discrete puff approach is depicted schematically in Figure 4-20.

Figure 4-20
Schematic Representation of Puff Superposition Approach in MSPUFF



The MSPUFF model utilizes an effective plume (puff) height which is the sum of the stack height and calculated plume rise. MSPUFF also treats conversion of SO_2 to sulfate, dry deposition, and wet deposition.

The dynamic MSPUFF model is driven with a two-dimensional gridded field of temporally and spatially varying meteorological input data. The gridded fields reflect a composite picture of hourly meteorological observations from all available stations (usually National Weather Service) in the Study area. Using these gridded fields of hourly meteorological data, solution of model equations directly yields 1-hour average pollutant concentrations. Concentrations for other averaging periods (e.g., 3-hour, 24-hour, annual) are achieved through simple averaging of sequential, hourly results. So that all potential seasonal variations are accounted for, the use of a full year of historical meteorological data with MSPUFF is desirable.

Source data required by MSPUFF are relative location, pollutant emission rate, stack height, stack diameter, stack gas exit velocity, and stack gas temperature for each emission point. Source data requirements for MSPUFF are essentially the same as for ISCST.

MSPUFF provides pollutant concentrations for all receptor locations specified by the user. Concentrations can be provided for a cartesian receptor grid, for discrete (individual) receptors, or both.

Finally, MSPUFF requires user selection of certain technical options which affect the treatment of advection, dispersion, SO_2-to-sulfate conversion, and wet and dry deposition in the model simulation. These options are normally set to values approved by EPA for regulatory analyses in North Dakota.

4.4.3 Source Data

Each of the four Class I areas was treated as a separate modeling problem, with separate sets of source input data, for the Williston Basin Study PSD Class I analysis. Because Class I allowable increments are considerably lower then Class II increments (and thus more sensitive to small additive impacts), PSD-increment-consuming SO_2 sources up to 250 km away from the center of the subject Class I area were addressed in the PSD Class I modeling analysis. The 250 km cutoff distance was established by the NDSDH in previous regulatory PSD Class I analyses in North Dakota.

Air quality impact of sources addressed in the PSD Class I analysis can be grouped as follows:

1) contribution of all major PSD-increment-consuming sources, other than oil and gas sources, which lie within 250 km of the center of the subject Class I area,

2) contribution of all PSD-increment-consuming oil and gas sources which lie within 50 km of the center of the subject Class I areas, and

3) contribution of all PSD-increment-consuming oil and gas sources which lie outside of a 50 km radius, but within 250 km of the center of the subject Class I area.

The contribution of PSD-increment-consuming oil and gas sources within 50 km was addressed using the ISCST model. The contribution of other major PSD-increment-consuming sources within 250 km was addressed using the MSPUFF model. The last component (3) was eliminated from consideration in the Class I analysis, as it was concluded that the impact of oil and gas sources located beyond 50 km from

Class I receptors would be insignificant. Therefore, model source input data were required for all PSD-increment-consuming lease-use treaters and active flares within 50 km, and for all other major PSD-increment-consuming sources within 250 km, of the center of the subject Class I area.

Source input data preparation for the ISCST model and the MSPUFF model is discussed in Sections 4.4.3.1 and 4.4.3.2, respectively.

4.4.3.1 Source Input Data for ISCST

The ISCST model was applied to PSD-increment-consuming oil and gas sources (lease-use treaters and active flares) which lie within 50 km of the center of each Class I area. Source data required by ISCST (summarized in Table 4-12) are location, stack-base elevation, pollutant emission rate, stack height, stack diameter, stack gas exit velocity, stack gas exit temperature, and source identification number for each emission point. Because of the relatively small number of receptors considered (Section 4.4.4), grouping of individual point sources into area sources to save computer time was not necessary for the PSD Class I analysis.

All necessary source input data for ISCST were obtained or derived from the emissions inventory for existing wells. The procedure used to develop source input data for ISCST is described below:

1) The emissions inventory for existing wells was searched to find all PSD-increment-consuming SO_2 sources (lease-use treaters and active flares) located within 50 km of the center of the subject Class I area. This step was accomplished with the development and execution of Fortran program PSDPTIN, as shown in Figure 4-18. The output of program PSDPTIN was a computer file containing well (permit) numbers for each well associated with a PSD-increment-consuming lease-use treater, or PSD-increment-consuming active flare, or both, located within 50 km of the Class I area. As shown in Figure 4-18, this computer file constituted input to program POINT.

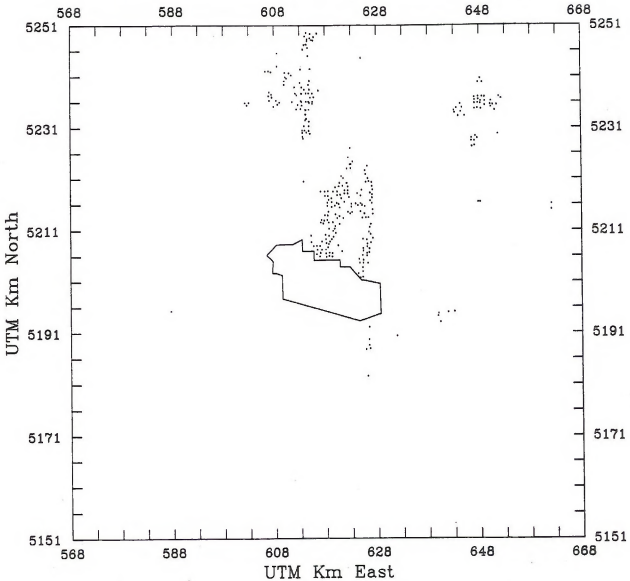
2) Final preparation of the ISCST source input file was accomplished with the execution of program POINT. Using the file of well numbers generated in Step 1 as keys, the emissions inventory for existing wells was searched by program POINT to determine the location, SO_2 emission rate, stack height, and heat of combustion for each PSD-increment-consuming lease-use treater and active flare which met the 50 km criteria. Virtual values for stack diameter, stack gas exit velocity, and stack gas exit temperature were subsequently determined from the heat of combustion using Equation (5) (from Section 4.3.3.2). A value for stack-base elevation was not required because elevation differences were not addressed in the PSD Class I analysis.

   Finally, program POINT assigned a sequence (identification) number for each source and assembled all source input data into an ISCST-compatible input file. The sequence number was comprised of the well number plus a specially coded digit to indicate whether the source reflected a treater or a flare.

   The execution of program POINT is depicted in Figure 4-18.

Maps showing the locations of ISCST input sources for each Class I area are included in Appendix B. The source-location map for the Theodore Roosevelt National Park - South Unit is included here as Figure 4-21. Note that these maps include the actual location of each treater and flare (i.e., not wellhead location). Note also that the reference to "PSD Sources" on the Class I maps implies PSD-increment-consuming sources.

Figure 4-21
Theodore Roosevelt National Park - South Unit
Locations of Existing PSD Sources of SO_2



4.4.3.2 Source Input Data for MSPUFF

The MSPUFF model was applied to major PSD-increment-consuming SO_2 sources, other than oil and gas sources, which lie within 250 km of the center of each Class I area. Source data required by MSPUFF are location, pollutant emission rate, stack height, stack diameter, stack gas exit velocity, and stack gas exit temperature for each emission point.

All necessary input data for major PSD-increment-consuming sources, located within 250 km of subject Class I areas, were obtained from NDSDH and MSDHES records. Input data for each source are listed in Table 4-17. Note that the X and Y values given for source location reflect a special coordinate system developed by the NDSDH for MSPUFF analyses. The Table 4-17 source data were manually assembled into an MSPUFF-compatible input file. The same input file was used for each Class I area.

Locations of the PSD-increment-consuming sources modeled with MSPUFF are shown in Figure 4-22.

4.4.4 Receptor Data

Because ISCST and MSPUFF results were added together to determine total Class I impact, the same receptor locations had to be utilized for both models. In previous MSPUFF regulatory Class I analyses, the NDSDH has used a constant set of 17 receptors for tracking PSD increment consumption. Included in this set are 8 receptors in the Teddy Roosevelt National Park (TRNP) South Unit, 7 receptors in the TRNP North Unit, and one receptor each in the TRNP Elkhorn Ranch Site and Lostwood National Wilderness Area.

Receptor locations in the TRNP South Unit and TRNP North Unit reflect an approximate 5 km spacing. The number of Class I receptors had to be limited because of the costs associated with execution of the MSPUFF model. Nevertheless, the 5 km spacing was concluded to be sufficient considering the average distance of major sources from Class I receptors, and the subsequent unlikelihood for concentration gradients within Class I areas to be significant.

To be consistent with PSD Class I analyses previously conducted by the NDSDH, the established set of 17 receptors was also utilized for the Williston Basin Study PSD Class I analysis. Coordinates of these receptor locations are provided in Table 4-18. Receptor locations with respect to Class I area boundaries for the TRNP-South and North Units are shown in Figure 4-23. The single receptors for the TRNP Elkhorn Ranch Site and the Lostwood National Wilderness Area are located roughly in the center of these Class I areas.

4.4.5 Meteorological Data

The steady-state ISCST model requires representative historical meteorological observations from a single station, preferably for at least one year of record. Meteorological data required include sequential hourly values for wind speed, wind direction, mixing height, stability class, and ambient temperature. Wind direction is used by the ISCST model to control the direction of plume transport. Wind speed controls the dispersion of effluent material along the length of the plume, while stability class (a measure of atmospheric turbulence) determines the crosswind rate of dispersion. Mixing height defines the available boundary layer through which mixing of the plume material can occur, and ambient temperature is used in plume rise calculations.

TABLE 4-17
MSPUFF Source Input Data

Source	SO_2 Emission (g/sec)	Stack Height (m)	Stack Diam. (m)	Exit Temp. (°K)	Exit Vel. (m/sec)	Grid Coordinates* X	Grid Coordinates* Y
Antelope Valley Station Units 1 and 2	484.9	182.9	7.0	356	23.2	5.75	5.00
Boxcar Butte Gas Plant	55.3	61.0	0.2**	1000**	112.3**	2.34	5.83
Coal Creek Station Units 1 and 2	1598.0	201.0	6.7	404	27.2	7.00	5.06
Coyote Generating Station	672.2	151.8	6.4	393	28.3	5.79	4.58
Enron Gas Plant	17.6	61.0	1.2	477	10.2	2.57	6.23
Great Plains Gasification Main Stack	505.0	125.3	4.9	472	30.8	5.76	4.98
Great Plains Gasification Start-up Flare	42.9	68.6	0.8**	1000**	94.2**	5.76	4.98
Great Plains Gasification Back-up Flare	80.0	30.5	1.8**	1000**	94.5**	5.76	4.98
Koch Williston Gas Plant	11.8	45.7	0.7	839	10.4	2.14	7.07
Little Knife Gas Plant	53.8	59.5	1.8	870	10.7	3.37	4.85
McKenzie County Gas Plant	34.4	65.0	1.0	950	19.1	1.70	5.72
Nokota Company Coal-to-Methanol Plant	327.6	152.4	11.2	394	12.2	4.43	4.85
Koch (Perry Pet.) Gas Plant (Montana)	25.0	54.9	0.1**	1000**	99.4**	1.61	5.98
ANR (Shell Oil) Gas Plant (Montana)	44.8	61.0	0.2**	1000**	56.2**	1.55	5.99
Teddy Roosevelt Gas Plant	28.4	30.5	1.1	866	15.0	3.11	4.37
Temple Gas Plant	14.6	25.9	0.2**	1000**	39.1**	3.62	8.38

*Grid coordinates are given in 40 km grid units. Origin of the grid system is located at 104.75° W. longitude, 45.50° N. latitude (near Ridgway, Montana).
**Virtual value for this parameter was developed to accommodate flare stack in conventional models.

Figure 4-22. Locations of PSD Sources

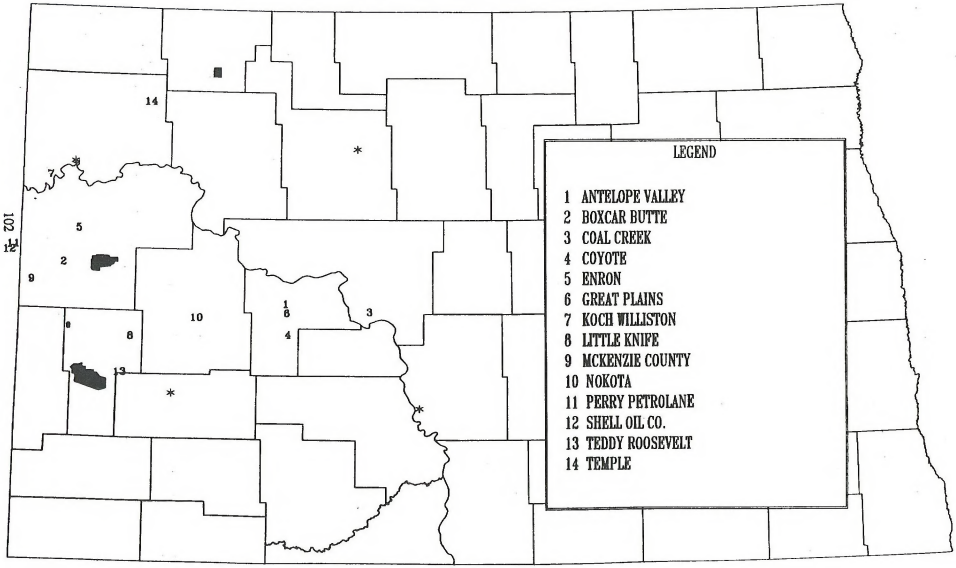


TABLE 4-18
PSD Class I Area Receptor Locations

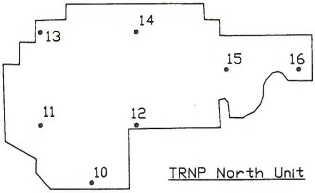
Receptor Number	UTM Coordinates (km)* East	North
TRNP-South Unit		
1	619.1	5197.0
2	623.9	5197.3
3	628.8	5197.6
4	613.5	5202.0
5	618.8	5202.3
6	623.6	5202.6
7	608.3	5206.6
8	613.2	5206.9
TRNP-Elkhorn Ranch Site		
9	604.8	5232.2
TRNP-North Unit		
10	621.2	5265.9
11	618.5	5270.3
12	623.4	5270.5
13	618.2	5275.2
14	623.1	5275.4
15	628.1	5273.3
16	631.8	5273.5
Lostwood NWA		
17	686.3	5393.0

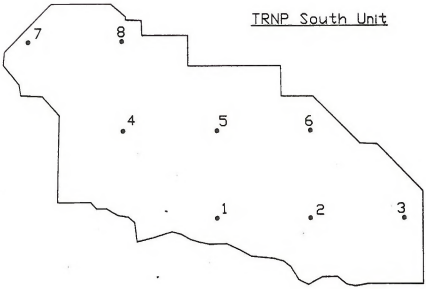
*All receptors are located in UTM Zone 13.

Meteorological data requirements for the dynamic MSPUFF model are considerably more complex than for ISCST. Though basic required parameters are similar (wind speed, wind direction, mixing height, stability class, ambient temperature), MSPUFF, because of its dynamic treatment of advection and dispersion, requires gridded (two-dimensional) input data to define spatial variations in meteorological conditions between sources and receptors. The preparation of gridded input data requires meteorological observations from more than one station, and preferably from all available stations in or close to the study area. In preparing meteorological data files for MSPUFF PSD Class I analyses in North Dakota, the NDSDH used data from all available NWS stations in or near North Dakota.

Because acquisition and preparation of input meteorological data for MSPUFF represents a considerable task, current data availability is limited to full-year input files for 1964, 1982, and 1983. The representativeness of 1983 Williston surface/Bismarck upper-air data for the ambient and PSD Class II ISCST analyses has already been demonstrated in Section 4.3.5. Thus, for representativeness and consistency, 1983 meteorological data were also utilized for the Williston Basin PSD Class I analysis. The 1983 Williston surface/Bismarck upper-air data set was used with ISCST and the 1983 composite, gridded data set was used with MSPUFF.

Figure 4-23
Receptor Locations for
TRNP North Unit and TRNP South Unit





4.4.6 Model Technical Options

The last component of model input preparation for the Williston Basin Study Class I analysis was the selection of technical options. Both ISCST and MSPUFF models allow the user to control various aspects of the simulation through selection of these input parameters. ISCST technical input options and usage for the WBS Class I analysis are summarized in Table 4-15. MSPUFF technical options, as deployed for the Williston Basin Study, are summarized in Table 4-19.

TABLE 4-19
MSPUFF Technical Options

Option	Williston Basin Study
Gridded receptors/Discrete receptors	Discrete
SO_2-to-sulfate conversion/No SO_2-to-sulfate conversion	SO_2-to-sulfate conversion
Dry deposition/No dry deposition	Dry deposition
Wet deposition/No wet deposition	Wet deposition
Length of basic time step	1 hour
Meteorological grid spacing	40,000 meters
Sampling grid spacing	20,000 meters
Puff release rate	2/hour
Puff sampling rate	8/hour
SO_2-to-sulfate conversion rate	-2.78×10^{-6}/sec
SO_2 deposition velocity	0.01 m/sec
Sulfate deposition velocity	0.001 m/sec
SO_2 wet deposition coefficient	3.0×10^{-5}/sec
Sulfate wet deposition coefficient	1.0×10^{-4}/sec

It is beyond the scope of this report to discuss the ISCST or MSPUFF technical options in detail. It suffices to say that, with the exception of stack-tip downwash and gradual plume rise, ISCST technical options were set according to EPA guidance for use of the model in regulatory analyses. The exceptions for ISCST stack-tip downwash and gradual plume rise were discussed in Section 4.3.6.

MSPUFF technical options were deployed according to guidance in the North Dakota Guideline for Air Quality Modeling Analyses. This guidance is based on previous NDSDH experience with use of the model in PSD Class I analyses, and has been reviewed and approved by EPA.

4.4.7 Model Execution

For each PSD Class I area, the ISCST and MSPUFF models were executed with source data, receptor data, meteorological data, and technical options as described in Sections 4.4.3 through 4.4.6. Execution of the

models is illustrated in the flow chart of Figure 4-19. As shown, model output obtained for the subject PSD Class I area analysis was a file containing sequential, back-to-back 3-hour average SO_2 concentrations for the entire year of meteorological data (2920 periods) for each receptor. Similar 3-hour files were produced by both the ISCST and MSPUFF models.

The 3-hour files from ISCST and MSPUFF were next added together, on the basis of concurrent 3-hour blocks, to produce a single combined file of sequential 3-hour concentrations which reflected the total contribution of all sources at each subject Class I area receptor. This step was accomplished with the development and execution of Fortran program WBSADD, as shown in Figure 4-19.

Finally, combined back-to-back 3-hour concentrations were averaged to produce 24-hour concentrations (365 periods) and an annual average concentration for each receptor, and all output information was summarized to yield the highest and second-highest 3-hour and 24-hour SO_2 concentration for each receptor (for comparison with applicable PSD Class I increments). This last step was accomplished with the development and execution of Fortran program WBSANAL, as shown in Figure 4-19.

4.5 Projections for Ambient H_2S Scenarios

Air quality projections for the existing and future ambient H_2S scenarios were not directly obtained with dispersion modeling. Rather, H_2S projections were obtained through a conversion of SO_2 modeling results using a stoichiometric relationship, which assumes a constant combustion efficiency for treaters and flares.

This simplified approach is the result of difficulty in quantifying and cataloging H_2S emissions from oil and gas facilities. Unlike SO_2, which is released to the atmosphere in a conventional manner from the combustion of sour gas in a flare or treater, H_2S emissions can result from random fugitive releases. As indicated in Section 3.2, H_2S emissions from oil and gas facilities are due to fugitive release of raw gas from leaky valves, pipe connections, or tank hatches, or from the incomplete combustion of gas at the treater or flare. As such, the character and amount of H_2S emissions are difficult to quantify for dispersion model treatment.

Due to a lack of data which could be used to quantify fugitive H_2S emissions from oil and gas facilities, it was concluded that H_2S projections should be addressed as the cumulative impact of components reflecting:

1) The contribution of H_2S emissions resulting from the incomplete combustion of gas at treaters and flares, and

2) The contribution of fugitive H_2S emissions resulting from leaky valves, tank hatches, pipe connections, or other fugitive sources.

It was concluded that the contribution of treater and flare H_2S emissions could be treated with conventional modeling, while the contribution of fugitive H_2S emissions would have to be addressed using a constant background concentration, which would be added to the modeled results.

In order to develop H_2S emission rates for treaters and flares, using either the SO_2 emission rates in the emissions inventory or production data in the SIC oil and gas data base, it was necessary to assume a

combustion efficiency for both treaters and flares. But the documented range of such values is significant, leaving the NDSDH and the BLM to conclude that the assumption of one, constant combustion efficiency for both treaters and flares is justified, and would simplify the H_2S ambient air quality analysis. The significance of the application of the same, constant combustion efficiency to both treaters and flares is that H_2S projections can be obtained through a relatively simple conversion of ambient SO_2 modeling results, thereby negating the need for an additional costly modeling procedure.

Thus, H_2S projections for the Williston Basin Study were obtained by combining:

1) The impact of treaters and flares, derived through a conversion of SO_2 ambient scenario modeling results, and

2) The impact of fugitive H_2S emissions, which was accounted for with a constant background concentration.

The conversion procedure is discussed in Section 4.5.1, and determination of the H_2S background concentration is described in Section 4.5.2.

4.5.1 Conversion of SO_2 Modeling Results

As indicated, H_2S projections were based on a conversion of SO_2 modeling results. The dispersion modeling procedure applied to the ambient SO_2 scenarios assumed 100% conversion of H_2S to SO_2 in treater and flare combustion. Thus, the relationship between predicted SO_2 concentration and potential H_2S concentration (if combustion efficiency was less than 100%) can be expressed generally as

$$\chi_{H_2S} = \chi_{SO_2}^{(1-\alpha)} \frac{M_{H_2S}}{M_{SO_2}}$$

where:

χ_{H_2S} = potential H_2S concentration

χ_{SO_2} = predicted SO_2 concentration

α = combustion efficiency for treaters and flares (assumed equal)

M_{H_2S} = molecular weight of H_2S

M_{SO_2} = molecular weight of SO_2

If combustion efficiency was zero, the difference between potential H_2S concentration and predicted SO_2 concentration would be reflected simply by the difference in molecular weights. Note that this relationship assumes that the predicted SO_2 concentration is due entirely to the impact of treaters and flares. This was concluded to be a reasonable assumption because the contribution of other types of sources to Study-field receptors was generally not significant.

Considering that background concentrations were added to SO_2 ambient scenario modeling results, and that an H_2S background concentration is to be used to account for H_2S fugitive releases, the relationship

between predicted SO_2 concentration and potential H_2S concentration can be expressed more specifically:

$$\chi_{H_2S} = (\chi_{SO_2} - b_{SO_2})(1 - \alpha) \frac{M_{H_2S}}{M_{SO_2}} + b_{H_2S}$$

where b_{SO_2} and b_{H_2S} reflect the background concentration for SO_2 and H_2S, respectively.

The NDSDH conducted a literature review to determine an appropriate value for treater and flare combustion efficiency. Documented values from field studies[24,25] and other sources[26], however, ranged from about 50 percent to nearly 100 percent. The broad range of reported values left the NDSDH unable to place a high level of confidence in any one source. Thus, after consultation with the BLM, it was concluded that a combustion efficiency reflecting the approximate average of reported values for both treaters and flares should be utilized, that being about 75 percent. Thus,

$$\chi_{H_2S} = (\chi_{SO_2} - b_{SO_2})(1 - .75) \frac{34.076}{64.06} + b_{H_2S}$$

or

$$\chi_{H_2S} = 0.133\,(\chi_{SO_2} - b_{SO_2}) + b_{H_2S}$$

which is the relationship used by the NDSDH to project 1-hour H_2S concentrations for the existing and future ambient scenarios.

4.5.2 Background Concentration

A background concentration was used to account for the impact of fugitive H_2S emissions. An H_2S background was developed for the 1-hour averaging period only, because only 1-hour H_2S projections were necessary to address the single ambient air quality standard (see Table 2-1).

The H_2S background concentration was derived from air quality monitoring data collected at NDSDH monitoring sites in the Study area (see Figure 3-3). The NDSDH operates H_2S monitors at the TRNP South Unit, TRNP North Unit, and at the Lostwood NWA. Because these monitoring sites are located in the general vicinity of oil and gas production, but are not close enough to any particular facility to be directly impacted by treater or flare emissions, it was concluded that observed H_2S concentrations at these sites would be reasonably representative of the regional impact of fugitive H_2S emissions.

To be consistent with the production period assumed for the WBS existing scenarios (November 1987 through March 1988), monitoring data for both 1987 and 1988 were used to develop the H_2S background concentration. A statistical frequency analysis was applied to TRNP South Unit, TRNP North Unit, and Lostwood NWA H_2S data to determine the 99th percentile hourly value for each year at each location. Use of the 99th percentile value is consistent with NDSDH policy regarding background concentrations, and guarantees a reasonable degree of conservatism. A single background was obtained by averaging the 99th percentile values for each year at each location (six values). The resultant 1-hour background concentration used in the WBS projection of H_2S ambient concentrations is 7.0 $\mu g/m^3$.

5. MODELING RESULTS AND INTERPRETATION

Dispersion modeling results are presented here for the Williston Basin Study existing ambient, future ambient, existing PSD Class II, future PSD Class II, and PSD Class I SO_2 scenarios, and for existing ambient and future ambient H_2S scenarios. Results are provided for each applicable averaging period (recall Tables 2-1 and 2-2). For each SO_2 and H_2S scenario, an attempt is made to describe the results in general for each field, and then to expand on any extreme or unique aspect of the predicted concentration pattern. Specifically, the discussion in this Section will:

1) Provide summaries of dispersion modeling results in tabular and graphical format for each SO_2 (tabular only for PSD Class I) and H_2S scenario.

2) Provide a narrative summarization of results in general for each SO_2 and H_2S scenario.

3) Point out extreme or unique aspects of the results for each SO_2 and H_2S scenario.

4) Compare existing scenario results with future scenario results for corresponding averaging periods.

5) Comment on how inclusion of terrain height variations may have affected dispersion modeling results (recall that, for economic and logistical reasons, terrain height variations were not addressed in the modeling analyses).

6) Comment on the meteorological conditions associated with highest predicted concentrations.

Modeling results for the ambient and PSD Class II SO_2 scenarios (existing and future) are discussed in Section 5.1. Modeling results for the PSD Class I SO_2 scenario are addressed in Section 5.2. Modeling results for the H_2S ambient scenarios (existing and future) are presented in Section 5.3. A discussion of the meteorological conditions associated with highest predicted concentrations for the Williston Basin Study is included as Section 5.4. Finally, all Williston Basin Study modeling results are summarized in Section 5.5.

5.1 Ambient and PSD Class II SO_2

Dispersion modeling results for the Williston Basin Study ambient and PSD Class II SO_2 scenarios were highly variable among the twelve Study fields. For some fields, predicted SO_2 air quality concentrations were low and relatively uniform, while other fields contained pockets of very high SO_2 concentrations where predictions greatly exceeded Ambient Air Quality Standards (AAQS) or PSD Class II allowable increments. These high predictions, however, tended to be very localized and, over most of the Study area, model predictions were within AAQS and PSD Class II allowable increments.

The extent of predicted exceedances of AAQS and PSD Class II allowable increments is summarized in Table 5-1. As shown, predicted AAQS exceedances for the existing ambient scenario were found in four of the twelve Study fields, while AAQS exceedances for the future ambient scenario were predicted in five fields. For the existing PSD Class II scenario, predicted exceedances of allowable increment were found in six Study fields, and for the future PSD Class II scenario, predicted exceedances were found in

eight of twelve Study fields. The Table 5-1 summary may be somewhat misleading in that exceedances tended to be very localized, covering a relatively small fraction of total Study-field area.

TABLE 5-1
Summary of Predicted Exceedances
of AAQS or PSD Class II Increments - SO_2

	Ambient Scenarios - Exceedance of Any AAQS Predicted?		PSD Class II Scenarios - Exceedance of Any Increment Predicted?	
Field	Existing	Future	Existing	Future
Big Stick	No	No	No	No
Buffalo Wallow	No	No	No	No
Charlson	No	No	No	No
Elkhorn Ranch	Yes	Yes	Yes	Yes
Little Knife	No	No	Yes	Yes
Lone Butte	Yes	Yes	Yes	Yes
Lost Bridge	Yes	Yes	No	Yes
Rough Rider	Yes	Yes	Yes	Yes
Scairt Woman	No	Yes	No	Yes
Smith	No	No	Yes	Yes
Stanley	No	No	Yes	Yes
Whiskey Joe	No	No	No	No

Dispersion modeling results for the ambient and PSD Class II SO_2 scenarios are discussed on a field-by-field basis in Sections 5.1.1 through 5.1.12. Results are presented in both tabular and graphical (contour plot) format for each applicable averaging period. Contour plots for selected scenarios and averaging periods are included and discussed in Sections 5.1.1 through 5.1.12. A complete set of contour plots, for all applicable averaging periods for each scenario for each Study field, are provided in Appendix C.

Contour plots were not prepared for the ambient scenario 3-hour SO_2 averages because the only applicable 3-hour AAQS, the Federal standard of 1300 $\mu g/m^3$, is clearly less constraining than the State 1-hour standard at 715 $\mu g/m^3$. It was therefore concluded that a detailed review of modeling results with respect to the 3-hour AAQS was unnecessary.

Note that comparisons with AAQS are based on highest predicted concentrations, while comparisons with allowable PSD increments are based on the second-highest predicted concentration at each receptor. The second-highest modeled values (except for annual average) are appropriately compared with allowable PSD increments because the regulations allow one exceedance of the applicable allowable increment per year (see Table 2-2), and one year of meteorological data was used with the model. The highest modeled values are compared with AAQS because the State AAQS (which are more constraining than Federal AAQS) allow no exceedances. Likewise, highest predicted concentrations are depicted in the contour plots for the ambient scenarios, while second-highest concentrations are depicted in the contour plots for the PSD Class II scenarios.

5.1.1 Big Stick Field

5.1.1.1 Ambient

As shown in Table 5-2, highest predicted SO_2 concentrations for the Big Stick existing and future ambient scenarios are well below AAQS for all averaging periods. The generally low SO_2 ambient concentrations predicted for the Big Stick Field are a product of the typically low H_2S percentages associated with wells in the Field coupled with the fact that a significant portion of the produced gas is sold rather than flared.

TABLE 5-2
Big Stick Field
Ambient Scenario Modeling Results - SO_2

Averaging Period	Location (UTM km) East	Location (UTM km) North	Predicted Concentration Modeled	Predicted Concentration Background	Predicted Concentration Total	AAQS N.D.	AAQS Federal
Existing Ambient Scenario Highest Predicted Concentrations (μg/m³)							
1-hour	618.4	5213.8	218.1	13.0	231.1	715	—
3-hour	618.4	5213.8	168.1	11.0	179.1	—	1300*
24-hour	618.4	5213.8	77.8	9.0	86.8	260	365*
Annual	618.4	5213.8	11.9	3.0	14.9	60	80
Future Ambient Scenario Highest Predicted Concentrations (μg/m³)							
1-hour	618.4	5213.8	220.8	13.0	233.8	715	—
3-hour	618.4	5213.8	169.6	11.0	180.6	—	1300*
24-hour	618.4	5213.8	80.0	9.0	89.0	260	365*
Annual	618.4	5213.8	12.8	3.0	15.8	60	80

*One exceedance per year is permitted.

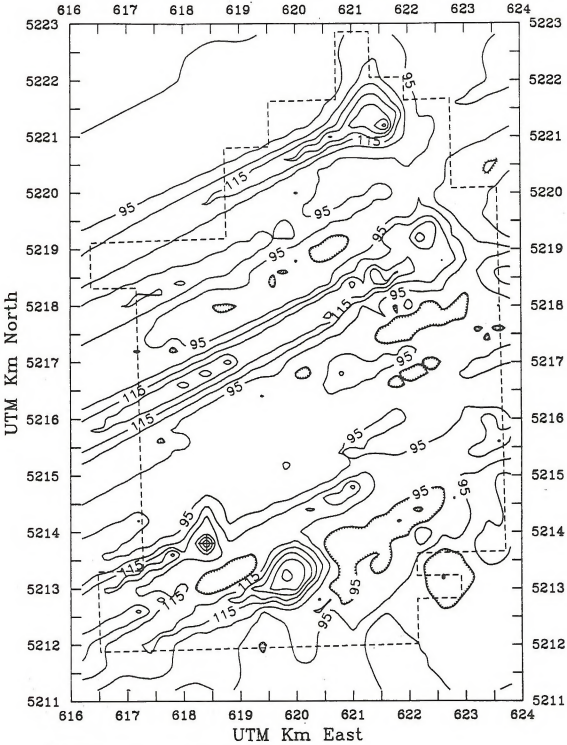
A contour plot of highest predicted 1-hour concentrations for the existing ambient scenario is provided as Figure 5-1. The contour interval, highest concentration (location of which is depicted with a "+" symbol within the contoured area), and applicable Ambient Air Quality Standard are noted at the bottom of the Figure. Map units are UTM kilometers. For reference purposes, the field boundary (dashed line) is also plotted on the Figure. Note that this contour plot does not reflect a single meteorological episode, but is rather a composite of the highest 1-hour concentrations predicted at each receptor, regardless of when they occurred (i.e., during the year of meteorological data used for modeling). Contour plots for other averaging periods and scenarios share the above characteristics.

The contours in Figure 5-1 reflect a relatively uniform SO_2 impact across the Field, with a few "pockets" of higher concentrations at the extreme north and south ends of the Field. These pockets portend the influence of higher-emitting sources within the field. Some of these stronger sources appear to produce elongated, elevated-concentration pockets extending toward the southwest, which are a result of limited vertical mixing because of low, morning mixing heights. But the general zonal (southwest to northeast)

Figure 5-1

Big Stick Field - Existing Ambient Scenario

Highest 1-hr SO_2 Concentrations ($\mu g/m^3$)



Highest Concentration (+) = 231

Ambient Air Quality Standard = 715 Contour Interval = 10

pattern of contours in the Figure suggests that overall results were significantly affected by sources located outside the Field.

The highest predicted 1-hour concentration is located in the southwest corner of the Field (this was consistent for all averaging periods). The "hot spot" appears to be produced by a central processing facility on-site of well number 7295 containing two treaters and a flare for well numbers 7295 and 7446.

As shown in Table 5-2, maximum SO_2 concentrations predicted for the future ambient scenario differed little from those predicted for the existing ambient scenario. This may be because future well development was projected primarily in the northern part of the Field, while maximum modeled concentrations for the existing scenario were found in the southwestern corner of the field. Thus, the additive impact of the future sources to highest existing SO_2 concentrations is minimized.

Contour plots of Big Stick modeling results for all averaging periods for both existing and future ambient scenarios are included in Appendix C.

5.1.1.2 PSD Class II

PSD Class II modeling results for the Big Stick Field are summarized in Table 5-3. As shown in the Table, the highest second-highest (HSH) predicted SO_2 concentrations for all averaging periods are within allowable PSD increments. It is also evident from Table 5-3 that there is little difference in HSH concentrations between the existing and future PSD Class II scenarios.

TABLE 5-3
Big Stick Field
PSD Class II Scenario Modeling Results - SO_2

Averaging Period	Location (UTM km) East	Location (UTM km) North	Predicted Concentration	Allowable Increment N.D.	Allowable Increment Federal
Existing PSD Class II Scenario Highest 2nd-Highest Predicted Concentrations (μg/m³)					
3-hour	618.4	5213.8	162.3	512*	512*
24-hour	618.4	5213.8	71.7	91*	91*
Annual	618.4	5213.8	11.8	15	20
Future PSD Class II Scenario Highest 2nd-Highest Predicted Concentrations (μg/m³)					
3-hour	618.4	5213.8	164.2	512*	512*
24-hour	618.4	5213.8	75.2	91*	91*
Annual	618.4	5213.8	12.7	15	20

*One exceedance per year is permitted.

Because of the absence of any non-PSD-increment-consuming sources in the Big Stick Field, the patterns of predicted SO_2 concentrations for the PSD Class II scenarios are similar to the patterns seen for the

ambient scenarios. Therefore, the comments made regarding characteristics of the ambient results would also be applicable to the PSD Class II results. Again, HSH SO_2 concentrations for all averaging periods were found in the southwest corner of the Field.

HSH SO_2 concentrations for 24-hour and annual averages reflected a higher percentage of allowable Class II increment than maximum 3-hour concentrations. Second-highest 24-hour concentrations for the PSD Class II existing scenario are depicted in Figure 5-2. Again pockets of elevated concentrations associated with more significant sources are evident in the Figure, and the HSH 24-hour concentration is located in the southwest corner of the Field.

Contour plots of Big Stick modeling results for all averaging periods for PSD Class II existing and future scenarios are included in Appendix C.

5.1.1.3 Terrain Effects

Terrain throughout the Big Stick Field can be characterized as generally rugged. The most extreme terrain feature is an elevated ridge running west to east through the middle of the field. Because of the possibility of plume impaction on elevated terrain under certain meteorological conditions, maximum predicted concentrations for ambient and PSD Class II scenarios may increase somewhat if terrain was be appropriately accounted for in the modeling analyses. However, the maximum terrain effects would probably be associated with the most significant terrain feature through the middle of the field, where predicted concentrations tend to be lower. Maximum predicted SO_2 concentrations in the southwest corner of the field would not be as significantly altered. Therefore, maximum SO_2 concentrations predicted using appropriate terrain adjustments would still likely be below AAQS for the ambient scenarios, and below or near allowable increments for the PSD Class II scenarios.

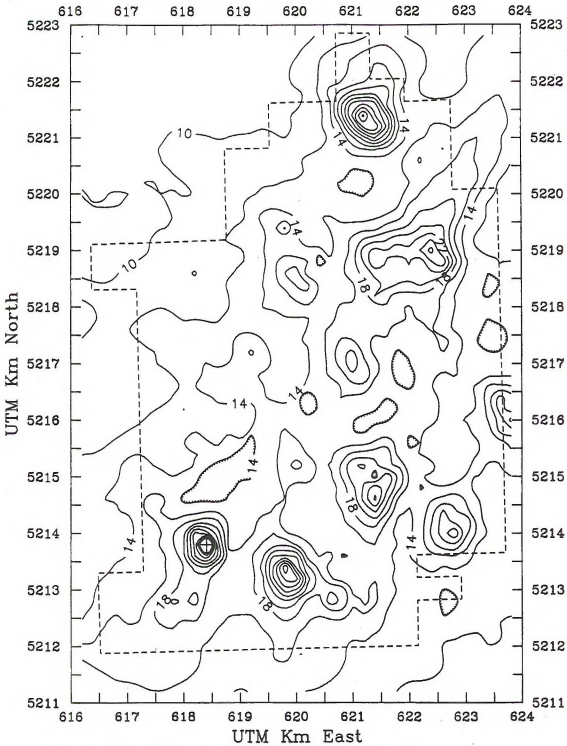
5.1.2 Buffalo Wallow Field

5.1.2.1 Ambient

Maximum predicted SO_2 concentrations for the Buffalo Wallow ambient scenarios are provided in Table 5-4. As shown, highest predicted concentrations are well below AAQS for all averaging periods. Though still well below AAQS, maximum predicted SO_2 concentrations for the future scenario are significantly higher than corresponding values for the existing scenario. The relatively low predicted SO_2 concentrations overall may be a result of low flaring activity (most gas from the field is sold).

Dispersion modeling results for 1-hour concentrations are characteristically different than those for other averaging periods for the Buffalo Wallow ambient scenarios. Contour plots of highest 1-hour and 24-hour predicted concentrations for the future ambient scenario are provided in Figures 5-3 and 5-4, respectively. The 1-hour SO_2 isopleths are very zonal (north-south), reflecting impact primarily from sources outside of the subject field. The 24-hour contour plot includes elevated-concentration pockets which distinctly reflect the locations of the facilities associated with the one existing well (northeast corner of Field) and two future wells (east-central part of Field) which are identified in Figure B-7 (Appendix B). The highest 24-hour concentrations are strongly influenced by the impact of one of the Buffalo Wallow future sources. For the 1-hour concentrations in Figure 5-3, impact from the three wells shows up as little more than perturbations in an otherwise zonal pattern, suggesting primary impact is from outside sources.

Figure 5-2
Big Stick Field – Existing PSD Class II Scenario
Second Highest 24-hr SO_2 Conc. ($\mu g/m^3$)

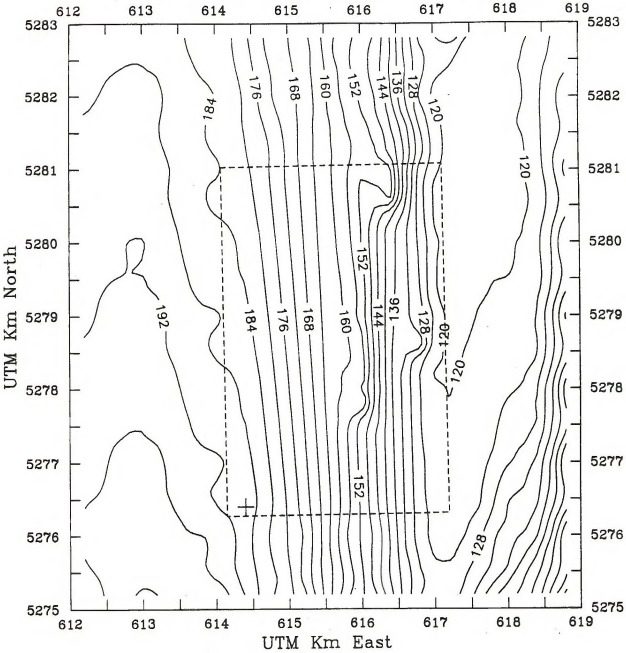


Highest 2nd Highest Concentration (+) = 72
PSD Class II Increment = 91 Contour Interval = 2

Figure 5-3

Buffalo Wallow Field – Future Ambient Scenario

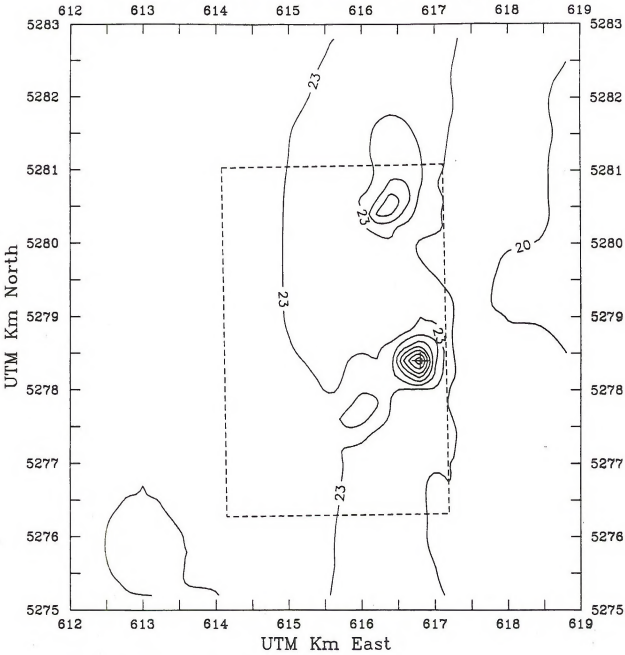
Highest 1-hr SO_2 Concentrations ($\mu g/m^3$)



Highest Concentration (+) = 191

Ambient Air Quality Standard = 715 Contour Interval = 4

Figure 5-4
Buffalo Wallow Field – Future Ambient Scenario
Highest 24-hr SO_2 Concentrations ($\mu g/m^3$)



Highest Concentration (+) = 46
Ambient Air Quality Standard = 260 Contour Interval = 1.5

TABLE 5-4
Buffalo Wallow Field
Ambient Scenario Modeling Results - SO_2

Averaging Period	Location (UTM km) East	Location (UTM km) North	Predicted Concentration Modeled	Predicted Concentration Background	Predicted Concentration Total	AAQS N.D.	AAQS Federal
Existing Ambient Scenario Highest Predicted Concentrations (μg/m³)							
1-hour	614.4	5276.4	118.4	13.0	131.4	715	—
3-hour	616.2	5280.4	61.4	11.0	72.4	—	1300*
24-hour	616.2	5280.4	19.9	9.0	28.9	260	365*
Annual	616.2	5280.4	3.3	3.0	6.3	60	80
Future Ambient Scenario Highest Predicted Concentrations (μg/m³)							
1-hour	614.4	5276.4	178.3	13.0	191.3	715	—
3-hour	616.8	5278.2	71.7	11.0	82.7	—	1300*
24-hour	616.8	5278.4	36.5	9.0	45.5	260	365*
Annual	616.8	5278.2	4.6	3.0	7.6	60	80

*One exceedance per year is permitted.

Contour plots for the existing ambient scenarios (Appendix C) reflect similar differences in pattern for the 1-hour average results versus results for other averaging periods. Perturbations or pockets reflecting the locations of the two future wells were not present, of course, in the existing scenario plots. Though contour patterns were similar, overall concentration levels for the existing scenario were lower than for the future scenario, indicating that future sources outside of the Buffalo Wallow Field contributed significantly to modeled predictions.

Contour plots for all averaging periods for Buffalo Wallow ambient scenarios are included in Appendix C.

5.1.2.2 PSD Class II

PSD Class II modeling results for the Buffalo Wallow Field are summarized in Table 5-5. As shown, the HSH predicted SO_2 concentrations are well below allowable PSD increments for all applicable averaging periods. HSH concentrations for the future scenario are larger than those for the existing scenario, but it appears that future sources located outside of the Buffalo Wallow Field accounted for most of the difference.

A contour plot of second-highest 3-hour SO_2 concentrations for the existing PSD Class II scenario is provided in Figure 5-5. The elevated-concentration pocket associated with the only existing well in the field is evident in the northeast corner. Note also that the lowest 3-hour concentrations within the plotted region (less than 18 μg/m³) occur primarily within the Buffalo Wallow Field boundary, again demonstrating the relatively large influence of outside sources.

TABLE 5-5
Buffalo Wallow Field
PSD Class II Scenario Modeling Results - SO_2

Averaging Period	Location (UTM km) East	Location (UTM km) North	Predicted Concentration	Allowable Increment N.D.	Allowable Increment Federal
Existing PSD Class II Scenario Highest 2nd-Highest Predicted Concentrations (μg/m³)					
3-hour	616.2	5280.4	49.2	512*	512*
24-hour	616.2	5280.4	18.8	91*	91*
Annual	616.2	5280.4	3.1	15	20
Future PSD Class II Scenario Highest 2nd-Highest Predicted Concentrations (μg/m³)					
3-hour	616.8	5278.4	59.6	512*	512*
24-hour	616.8	5278.4	25.2	91*	91*
Annual	616.8	5278.2	4.4	15	20

*One exceedance per year is permitted.

Contour plots for all averaging periods for Buffalo Wallow PSD Class II scenarios are included in Appendix C.

5.1.2.3 Terrain Effects

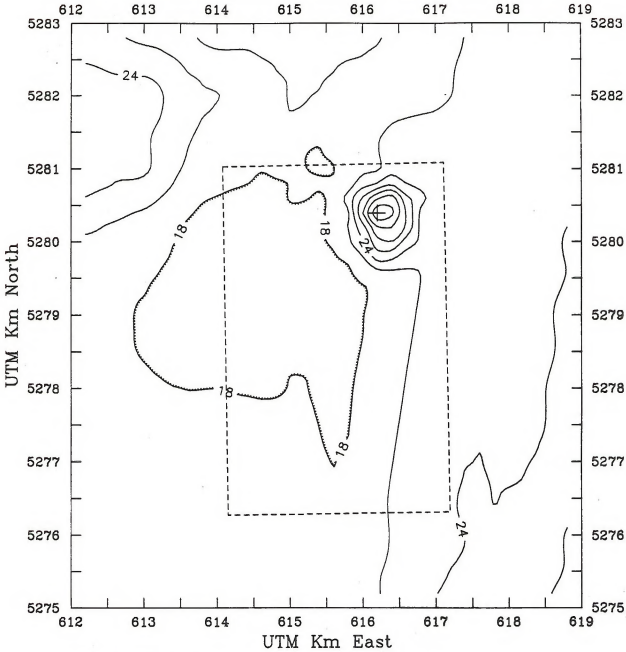
Terrain elevation in the Buffalo Wallow Field increases generally from northwest to southeast, with the most rugged terrain in the southeast quarter of the field. Given the relatively even terrain in the northeast part of the Field (where the one existing well is located), it is unlikely that predicted concentrations for existing scenarios would have substantively changed if terrain effects were addressed. There is more potential for increases in concentrations for future scenarios, because future Buffalo Wallow sources are projected to be located in an area of more rugged terrain. However, maximum predicted concentrations would still likely be well below applicable AAQS and allowable PSD increments.

5.1.3 Charlson Field

5.1.3.1 Ambient

Maximum predicted SO_2 concentrations for the Charlson Field ambient scenarios are provided in Table 5-6. As indicated, highest predicted concentrations for both existing and future scenarios are well below AAQS for all averaging periods. Maximum predicted SO_2 concentrations for the future scenario are significantly higher than corresponding values for the existing scenario. Relatively low SO_2 concentrations in the Charlson Field are due to the tie-in of most wells to a gas processing plant (Tioga), and the use of processed (sweet) gas for treater fuel.

Figure 5-5
Buffalo Wallow Field - Existing PSD Class II Scen.
Second Highest 3-hr SO_2 Conc. ($\mu g/m^3$)



Highest 2nd Highest Concentration (+) = 49

PSD Class II Increment = 512 Contour Interval = 3

TABLE 5-6
Charlson Field
Ambient Scenario Modeling Results - SO_2

Averaging Period	Location (UTM km) East	Location (UTM km) North	Predicted Concentration Modeled	Predicted Concentration Background	Predicted Concentration Total	AAQS N.D.	AAQS Federal
Existing Ambient Scenario Highest Predicted Concentrations (μg/m³)							
1-hour	656.6	5325.6	126.6	13.0	139.6	715	—
3-hour	656.4	5326.4	74.8	11.0	85.8	—	1300*
24-hour	652.8	5324.2	32.9	9.0	41.9	260	365*
Annual	652.0	5324.4	5.4	3.0	8.4	60	80
Future Ambient Scenario Highest Predicted Concentrations (μg/m³)							
1-hour	653.4	5323.2	204.7	13.0	217.7	715	—
3-hour	653.4	5323.2	150.3	11.0	161.3	—	1300*
24-hour	653.4	5323.2	46.5	9.0	55.5	260	365*
Annual	653.4	5323.2	6.1	3.0	9.1	60	80

*One exceedance per year is permitted.

Like the Buffalo Wallow results, contour plots of highest predicted SO_2 concentrations for the Charlson Field (included in Appendix C for all averaging times for existing and future scenarios) demonstrated significant influence of sources located outside of the subject field. Like Buffalo Wallow, plots for Charlson 1-hour concentrations exhibit a zonal pattern with the impact of individual subject-field sources barely detectable. One-hour concentrations for both existing and future scenarios increase from south to north across the Charlson Field, reflecting the influence of sources to the north.

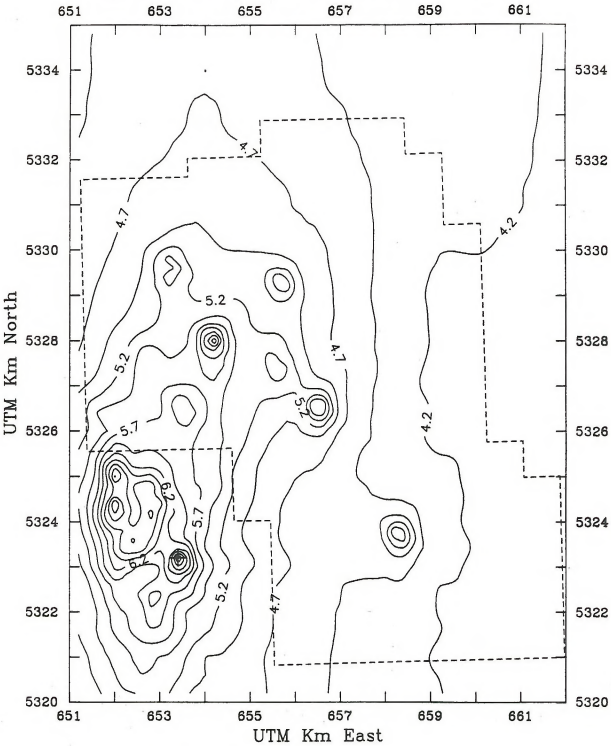
Contour plots for 24-hour and annual average SO_2 concentrations exhibited influence primarily from the Keene Field, located immediately southwest of the Charlson Field. The plot of highest annual average concentrations for the future ambient scenario is provided in Figure 5-6. The influence of the Keene Field (immediately southwest) is apparent from the contour pattern. The maximum annual average concentration for the plotted area is found in the Keene field. Elevated-concentration pockets associated with Charlson well installations are also evident in the plot.

5.1.3.2 PSD Class II

Dispersion modeling results for the Charlson Field PSD Class II scenarios are summarized in Table 5-7. As indicated in the Table, the HSH predicted SO_2 concentrations are well below allowable PSD increments for all applicable averaging periods, for both existing and future scenarios. Impact from the nearby Keene Field largely influences the HSH predicted concentrations for all three averaging periods.

Contour plots for the PSD Class II scenarios exhibited patterns similar to the plots for the ambient scenarios. Again, the HSH concentrations within the modeled region were found in the Keene Field, southwest of Charlson. The plot of highest annual averages for the PSD Class II future scenario is

Figure 5-6
Charlson Field – Future Ambient Scenario
Annual Average SO_2 Concentrations ($\mu g/m^3$)



Highest Concentration (+) = 9.1
Ambient Air Quality Standard = 60 Contour Interval = 0.25

provided in Figure 5-7. Note that, although the overall magnitude of annual average SO_2 concentrations is lower, the isopleth pattern is very similar to the Figure 5-6 pattern for the ambient future scenario.

TABLE 5-7
Charlson Field
PSD Class II Scenario Modeling Results - SO_2

Averaging Period	Location (UTM km) East	Location (UTM km) North	Predicted Concentration	Allowable Increment N.D.	Allowable Increment Federal
Existing PSD Class II Scenario Highest 2nd-Highest Predicted Concentrations (μg/m³)					
3-hour	652.0	5324.4	70.3	512*	512*
24-hour	652.0	5324.4	29.7	91*	91*
Annual	652.0	5324.4	4.7	15	20
Future PSD Class II Scenario Highest 2nd-Highest Predicted Concentrations (μg/m³)					
3-hour	653.4	5323.2	113.6	512*	512*
24-hour	653.4	5323.2	44.6	91*	91*
Annual	653.4	5323.2	5.3	15	20

*One exceedance per year is permitted.

Contour plots for all averaging periods for Charlson PSD Class II scenarios can be found in Appendix C.

5.1.3.3 Terrain Effects

Terrain in the vicinity of the Charlson Field can be characterized as gently rolling in the southern part of the Field, but with an abrupt transition to deeply channeled terrain in the central and northern part of the field. The channeling is a result of current drainage to Lake Sakakawea and formerly to the Missouri River. Because of the extreme terrain height variations in the northern part of the field, it is difficult to assess the effect on modeled concentrations of proper consideration of terrain in the modeling process. The impact would likely be greater on predicted concentrations in the Charlson Field than on the maximums found in the Keene Field further south. On balance, however, it does not seem likely that SO_2 concentrations in the Charlson Field would increase to the point of exceeding AAQS or PSD allowable increments if terrain was properly addressed.

5.1.4 Elkhorn Ranch Field

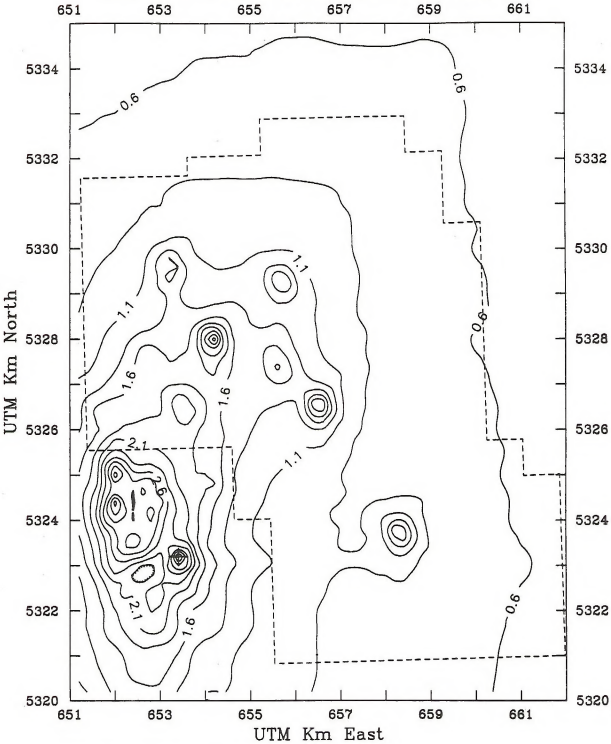
5.1.4.1 Ambient

Maximum predicted SO_2 concentrations for the Elkhorn Ranch Field ambient scenarios are summarized in Table 5-8. As shown, maximum predicted concentrations exceed AAQS for 1-hour, 3-hour, and 24-hour averaging periods for both existing and future scenarios. Though maximum predicated concentra-

Figure 5-7

Charlson Field - Future PSD Class II Scenario

Annual Average SO_2 Concentrations ($\mu g/m^3$)



Highest Concentration (+) = 5.3

PSD Class II Increment = 15

Contour Interval = 0.25

tions for those averaging periods exceed AAQS by a significant margin, the areal extent of exceedance is very limited, as is evident in the plotted results for the Field. Maximum concentrations for the receptor grid actually occurred in the North Elkhorn Ranch Field, rolling off to values generally below AAQS in the Elkhorn Ranch Field. The elevated-concentration area in the North Elkhorn Ranch Field is a result of impact primarily from two short flares with relatively high SO_2 emission servicing well numbers 9567 and 8671 at a central processing facility on-site of well number 8430.

TABLE 5-8
Elkhorn Ranch Field
Ambient Scenario Modeling Results - SO_2

Averaging Period	Location (UTM km) East	Location (UTM km) North	Predicted Concentration Modeled	Predicted Concentration Background	Predicted Concentration Total	AAQS N.D.	AAQS Federal
Existing Ambient Scenario Highest Predicted Concentrations (μg/m³)							
1-hour	614.2	5234.6	1789.5	13.0	1802.5	715	—
3-hour	614.2	5234.6	1418.8	11.0	1429.8	—	1300*
24-hour	614.2	5234.6	435.5	9.0	444.5	260	365*
Annual	614.2	5234.6	53.1	3.0	56.1	60	80
Future Ambient Scenario Highest Predicted Concentrations (μg/m³)							
1-hour	614.2	5234.6	1789.5	13.0	1802.5	715	—
3-hour	614.2	5234.6	1418.9	11.0	1429.9	—	1300*
24-hour	614.2	5234.6	437.7	9.0	446.7	260	365*
Annual	614.2	5234.6	55.3	3.0	58.3	60	80

*One exceedance per year is permitted.

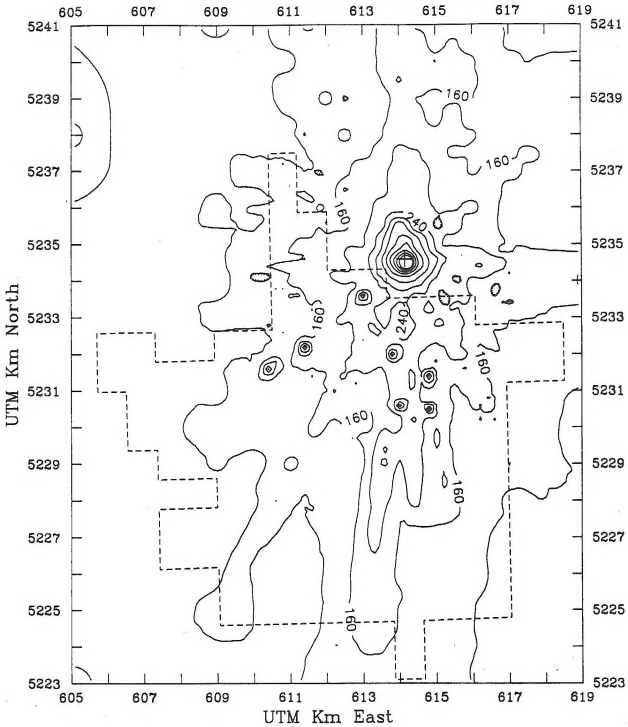
Contour plots of highest 1-hour SO_2 concentrations for the Elkhorn Ranch Field existing and future ambient scenarios are provided in Figures 5-8 and 5-9, respectively. The elevated-concentration area in the North Elkhorn Ranch Field (adjacent to the Elkhorn Ranch Field on the north side) is evident for both scenarios. Note that the highest 1-hour isopleth actually plotted is 520 μg/m³ for the existing scenario and 560 μg/m³ for the future scenario. These values are clearly much lower than the highest concentration indicated (1803 μg/m³). Higher-value contours were not plotted because increasingly dense contour spacing would have rendered them difficult to resolve, and because the "+" symbol used to designate the position of the overall highest concentration would have been obscured. For the same reason, some higher-value contours were deleted from plots for other averaging periods and scenarios for the Elkhorn Ranch Field, and plots for other fields, as well.

It is evident from Figures 5-8 and 5-9 that the areal coverage of AAQS exceedance is very small, especially considering that the highest-value contour plotted is significantly lower than the 1-hour AAQS (715 μg/m³). The tendency for very small areal coverage of AAQS exceedance was also seen in the existing and future scenario plots for 24-hour averages, which are included in Appendix C. No annual average exceedances were predicted for either existing or future Elkhorn Ranch scenarios (plots in Appendix C).

Figure 5-8

Elkhorn Ranch Field – Existing Ambient Scenario

Highest 1-hr SO_2 Concentrations ($\mu g/m^3$)



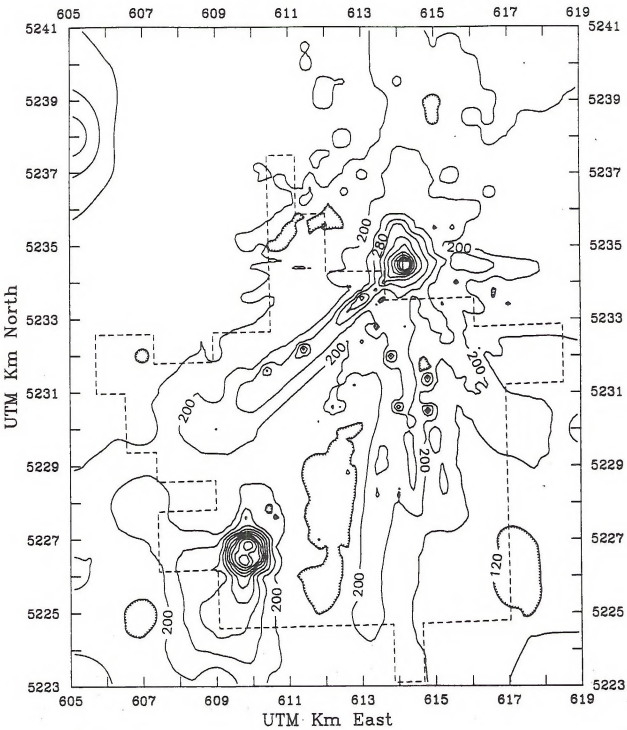
Highest Concentration (+) = 1803

Ambient Air Quality Standard = 715 Contour Interval = 40

Figure 5-9

Elkhorn Ranch Field - Future Ambient Scenario

Highest 1-hr SO_2 Concentrations ($\mu g/m^3$)



Highest Concentration (+) = 1803

Ambient Air Quality Standard = 715 Contour Interval = 40

In comparing Figures 5-8 and 5-9, maximum concentrations in general are higher for the future scenario than for the existing scenario. However, the overall highest predicted concentration (1803 $\mu g/m^3$) is the same for both scenarios, indicating that the highest predicted concentration for both scenarios is dominated by impact from an existing source. The future scenario plot of 1-hour concentrations also includes a secondary pocket of elevated concentrations which is located in the southwest corner of the Field. This elevated-concentration pocket appears to be the result of impact primarily from two future wells (F22 and F23 in Figure B-15, Appendix B). The similarity in highest overall concentrations for both the existing and future scenarios, and the secondary pocket of elevated concentrations in the southwest part of the Field, were also noted in the Elkhorn Ranch ambient scenario plots for other averaging periods (Appendix C).

5.1.4.2 PSD Class II

Dispersion modeling results for the Elkhorn Ranch Field PSD Class II scenarios are summarized in Table 5-9. As indicated, the HSH predicted SO_2 concentrations exceed maximum allowable increment by a significant margin for all three averaging periods for both PSD Class II scenarios. Though the areal extent of Class II increment exceedances is still relatively small, it is significantly larger than the extent of AAQS exceedances, particularly for the future scenario. Again, the Class II exceedance region was confined mostly to the North Elkhorn Ranch Field. Class II increment exceedances are probably due to the relatively dense siting of well installations in the northern part of the Elkhorn Ranch Field and the southern part of the North Elkhorn Ranch Field. Because of the larger extent of Class II increment exceedances, they cannot be attributed to a few individual sources, as was the case for Elkhorn Ranch AAQS exceedances.

TABLE 5-9
Elkhorn Ranch Field
PSD Class II Scenario Modeling Results - SO_2

Averaging Period	Location (UTM km) East	Location (UTM km) North	Predicted Concentration	Allowable Increment N.D.	Allowable Increment Federal
Existing PSD Class II Scenario Highest 2nd-Highest Predicted Concentrations ($\mu g/m^3$)					
3-hour	614.2	5234.6	1357.2	512*	512*
24-hour	614.2	5234.6	429.4	91*	91*
Annual	614.2	5234.6	52.6	15	20
Future PSD Class II Scenario Highest 2nd-Highest Predicted Concentrations ($\mu g/m^3$)					
3-hour	614.2	5234.6	1357.5	512*	512*
24-hour	614.2	5234.6	429.7	91*	91*
Annual	614.2	5234.6	54.9	15	20

*One exceedance per year is permitted.

The contour plot of annual average SO_2 concentrations for the Elkhorn Ranch future PSD Class II scenario is provided in Figure 5-10. The highest annual average concentration, as seen in the Figure, is located in the North Elkhorn Ranch Field, near the border with the Elkhorn Ranch Field. The 15 $\mu g/m^3$ isopleth on the plot encloses a significant region of allowable-increment exceedance in the North Elkhorn Ranch Field, and very localized exceedance pockets in the northeastern and southwestern parts of the Elkhorn Ranch Field.

The contour pattern for 3-hour and 24-hour second-high concentrations for the future PSD Class II scenario (Appendix C) was very similar to the pattern for annual averages, and exceedances of 3-hour and 24-hour allowable increments were also noted in those plots. Total areal coverage of exceedance, however, was greatest for the annual average. Contour patterns for the existing PSD Class II scenario were very similar to those for the future scenario, with the exception that the elevated-concentration pocket in the southwest corner of the field (due to impact from sources associated with two future wells) was not present in the existing scenario plots (existing plots in Appendix C).

To clarify results for planning purposes, an additional graphical interpretation of results is introduced for the Elkhorn Ranch PSD Class II scenarios. The "normalized-composite" plot provides a composite picture of results for all averaging periods for one scenario. The normalized-composite plot for the Elkhorn Ranch PSD Class II existing scenario is included as Figure 5-11 and the normalized-composite plot for the Elkhorn Ranch PSD Class II future scenario is included as Figure 5-12. These plots were prepared by normalizing the second-highest predicted concentration with respect to the allowable Class II increment for each averaging period, then selecting the highest resultant value at each receptor location. The plotted value was thus obtained for each receptor location as

$$\chi p = \max \left[\left(\frac{\chi\, 3\text{-hr}}{3\text{-hr Inc}} \times 100\% \right), \left(\frac{\chi\, 24\text{-hr}}{24\text{-hr Inc}} \times 100\% \right), \left(\frac{\chi\, \text{Ann.}}{\text{Ann. Inc.}} \times 100\% \right) \right]$$

where:

χp = normalized plotted value for receptor,

χ 3-hr' 24-hr = second-highest predicted SO_2 concentration at receptor,

χ Ann. = predicted annual average SO_2 concentration at receptor,

Inc = allowable Class II increment (North Dakota),

max = maximum of the three quantities within the major brackets.

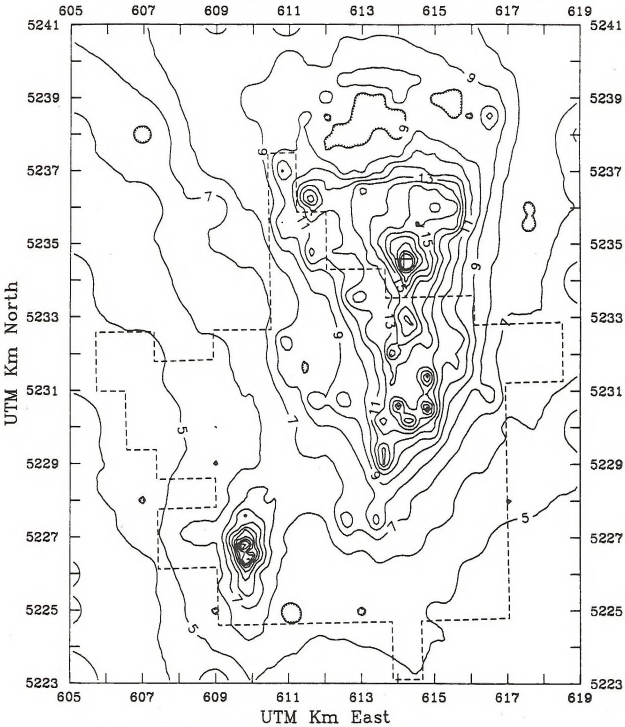
The final plot was obtained by applying a contour-plotting software procedure to the resultant, composite field of normalized values. The 100% contour thus encloses the composite region of predicted exceedances for all averaging periods, i.e., the region over which at least one allowable increment (but not necessarily all) is predicted to be exceeded.

Though not utilized for the Elkhorn Ranch Field, normalized-composite plots for ambient scenarios were also prepared for some Study fields. For ambient scenarios, the plotted value at each receptor location was obtained by

Figure 5-10

Elkhorn Ranch Field - Future PSD Class II Scen.

Annual Average SO_2 Concentrations ($\mu g/m^3$)

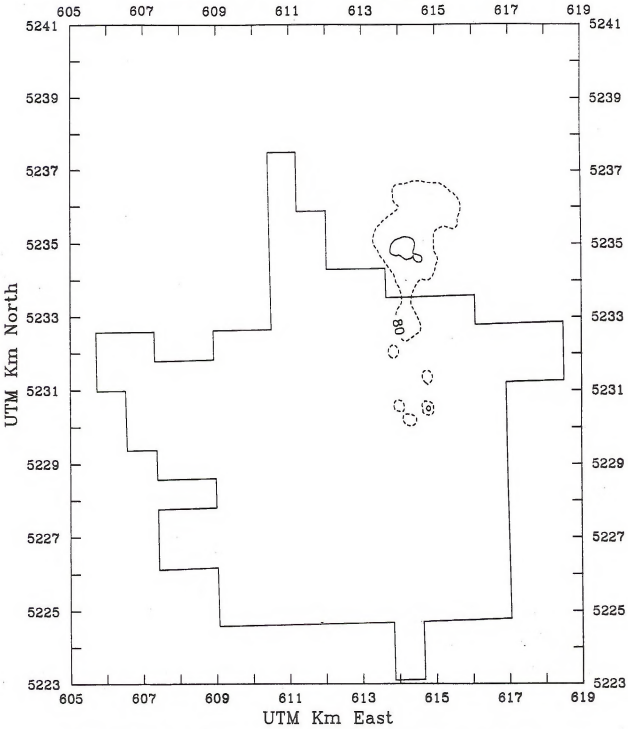


Highest Concentration (+) = 55

PSD Class II Increment = 15

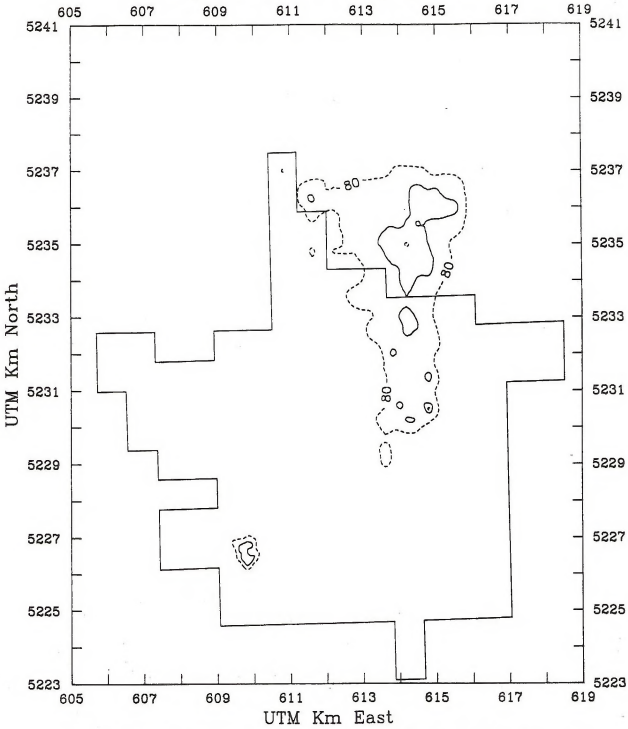
Contour Interval = 1

Figure 5-11
Elkhorn Ranch Field - Existing PSD Class II Scen.
2nd High SO_2 Conc. Normalized w.r.t. PSD Incr.
Composite of All Averaging Periods



Contour Units = Percent Contour Interval = 20

Figure 5-12
Elkhorn Ranch Field - Future PSD Class II Scen.
2nd High SO_2 Conc. Normalized w.r.t. PSD Incr.
Composite of All Averaging Periods



Contour Units = Percent Contour Interval = 20

$$\chi_p = \max \left[\left(\frac{\chi_{1\text{-hr}}}{\text{1-hr AAQS}} \times 100\% \right), \left(\frac{\chi_{24\text{-hr}}}{\text{24-hr AAQS}} \times 100\% \right), \left(\frac{\chi_{\text{Ann.}}}{\text{Ann. AAQS}} \times 100\% \right) \right]$$

where:

χ_p = normalized plotted value for receptor,

$\chi_{1\text{-hr}}$, $\chi_{24\text{-hr}}$ = highest predicted SO_2 concentration at receptor,

$\chi_{\text{Ann.}}$ = predicted annual average SO_2 concentration at receptor,

AAQS = Ambient Air Quality Standard (North Dakota),

max = maximum of the three quantities within the major brackets.

Note that 3-hour ambient concentrations are not addressed in the determination of the plotted value above, even though a 3-hour AAQS exists (Federal). This is because the 1-hour normalized value would always be greater than the 3-hour normalized value, given the lower 1-hour AAQS.

Normalized-composite plots were not prepared for Elkhorn Ranch ambient scenarios because the areal extent of exceedance was so localized that the 100% contour would have been virtually undetectable on the plots. In general, composite plots were only prepared for those fields and scenarios where exceedances of applicable air quality values were predicted.

The normalized-composite plots are intended to clarify the interpretation of results when exceedances of AAQS or PSD Class II increments are predicted. Rather than having to ascertain the total areal extent of exceedances from three different plots, a single normalized-composite plot for each scenario can be used for more direct interpretation. Furthermore, the normalized-composite plots include only the 80%, 100%, and 120% (if present) contours, thus reducing the number of potentially confusing isopleths present.

Returning to Figures 5-11 and 5-12, the increase in areal extent of PSD Class II exceedances with the future Elkhorn Ranch scenario is apparent. While existing scenario exceedances are generally limited to the North Elkhorn Ranch Field, future scenario exceedances are found in several local areas of the Elkhorn Ranch Field. It is also apparent that annual average results were the primary influence on the normalized-composite plot for the future scenario. This can be seen from a comparison of Figure 5-12 with Figure 5-10 (annual average contour plot). If the 15 $\mu g/m^3$ contour (reflecting allowable increment) is traced in Figure 5-10, it has virtually the same shape as the 100% contour in Figure 5-12. Also, the 12 $\mu g/m^3$ contour in Figure 5-10 is nearly the same shape as the 80% contour in Figure 5-12.

5.1.4.3 Terrain Effects

The Elkhorn Ranch Field is characterized by continuous rugged terrain. Undoubtedly, incorporation of terrain effects in dispersion model calculations would alter model results for this Field. However, because of the absence of wells in the western and southern part of the field, current modeling results for those areas would still be meaningful to the extent that they suggest future development is possible. A modeling analysis which incorporated terrain effects would probably project higher maximum concentrations and a larger exceedance area for the northern part of the Elkhorn Ranch Field, and for the North Elkhorn Ranch

Field. But it is not likely that terrain-enhanced impacts would extend into the western and southern zones of the Elkhorn Ranch Field, given the configuration of existing well locations.

5.1.5 Little Knife Field

5.1.5.1 Ambient

Maximum predicted SO_2 concentrations for the Little Knife Field ambient scenarios are summarized in Table 5-10. As shown, maximum predicted concentrations are below AAQS for each applicable averaging period for both existing and future scenarios. Most of the gas in the Little Knife Field is channeled to a nearby gas processing plant (Little Knife), thus possibly accounting for the relatively low ambient SO_2 concentrations.

TABLE 5-10
Little Knife Field
Ambient Scenario Modeling Results - SO_2

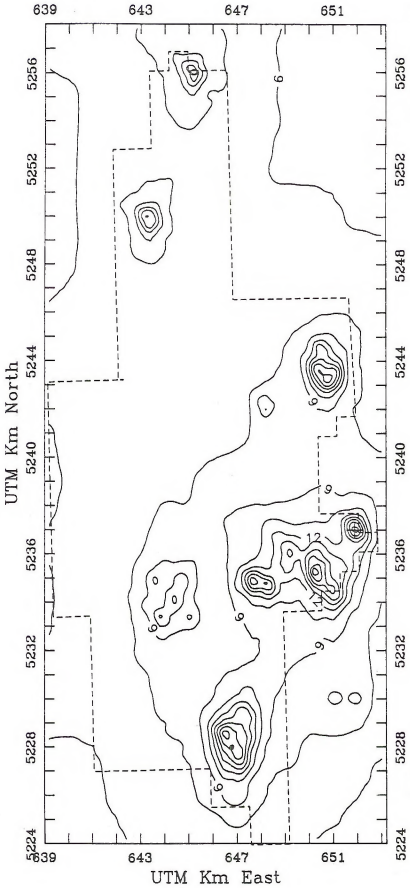
Averaging Period	Location (UTM km) East	Location (UTM km) North	Predicted Concentration Modeled	Predicted Concentration Background	Predicted Concentration Total	AAQS N.D.	AAQS Federal
Existing Ambient Scenario Highest Predicted Concentrations (μg/m³)							
1-hour	647.8	5235.0	574.9	13.0	587.9	715	—
3-hour	651.9	5237.2	499.6	11.0	510.6	—	1300*
24-hour	652.0	5237.1	184.8	9.0	193.8	260	365*
Annual	651.9	5237.0	26.0	3.0	29.0	60	80
Future Ambient Scenario Highest Predicted Concentrations (μg/m³)							
1-hour	647.8	5235.0	576.8	13.0	589.8	715	—
3-hour	651.9	5237.2	499.6	11.0	510.6	—	1300*
24-hour	652.0	5237.1	186.7	9.0	195.7	260	365*
Annual	651.9	5237.0	26.9	3.0	29.9	60	80

*One exceedance per year is permitted.

The configuration of elevated-concentration areas in the Little Knife Field is consistent with the configuration of well locations (Appendix B). The contour plot of annual average SO_2 concentrations for the existing scenario is shown in Figure 5-13. In comparing this Figure with the map of source locations in Appendix B, the association of elevated-concentration pockets with source locations is readily apparent. Densest well spacing and highest predicted concentrations are both found in the east-central part of the field. Contour plots for existing scenario 1-hour and 24-hour averages (Appendix C) exhibit similar patterns.

Figure 5-13

Little Knife Field
Existing Ambient S.
Annual Average SO_2
Conc. ($\mu g/m^3$)



Contour Interval = 1.5
Highest Conc. (+) = 29
AAQS = 60

Contour plots for all averaging periods for the Little Knife future ambient scenario are included in Appendix C. Other than to raise overall predicted concentrations slightly, the addition of future wells appears to have a minimal effect on modeling results for the Little Knife Field. Contour patterns for corresponding averaging periods are very similar between the Little Knife existing ambient and future ambient scenarios.

5.1.5.2 PSD Class II

Dispersion modeling results for the Little Knife Field PSD Class II scenarios are summarized in Table 5-11. As indicated in Table 5-11, predicted HSH SO_2 concentrations exceed maximum allowable increments for 24-hour and annual averaging periods for both scenarios, but do not exceed allowable increments for 3-hour averages. The tendency for longer-term averages to be more restrictive was seen in the results for some other fields, as well. This tendency was anticipated because of the density of well installations found in many of the subject fields, including Little Knife. Longer-term AAQS or PSD Class II increments are more likely to be threatened than short-term values when sources are scattered around the receptor(s) of concern (as opposed to a single-source situation), because some impact will occur with any wind direction. Longer-term averages are not usually as constraining in the case of isolated single sources because only one wind direction (essentially) will cause impact at a given receptor.

TABLE 5-11
Little Knife Field
PSD Class II Scenario Modeling Results - SO_2

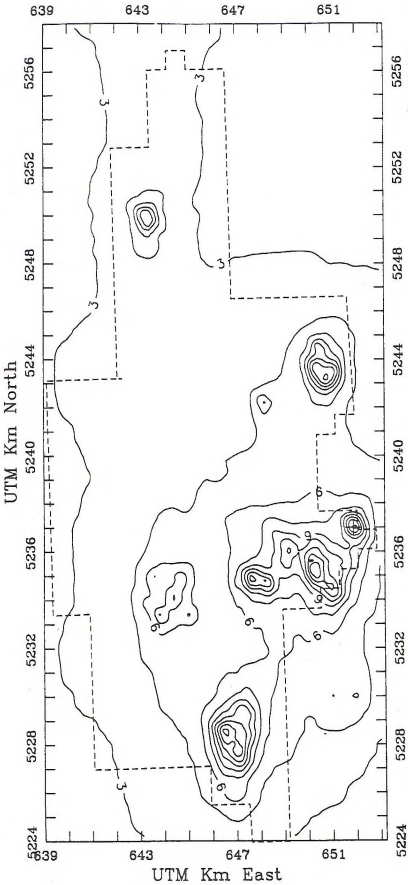
Averaging Period	Location (UTM km) East	Location (UTM km) North	Predicted Concentration	Allowable Increment N.D.	Allowable Increment Federal
Existing PSD Class II Scenario Highest 2nd-Highest Predicted Concentrations (μg/m³)					
3-hour	651.9	5237.2	413.2	512*	512*
24-hour	651.9	5237.0	159.7	91*	91*
Annual	651.9	5237.0	25.8	15	20
Future PSD Class II Scenario Highest 2nd-Highest Predicted Concentrations (μg/m³)					
3-hour	651.9	5237.2	413.2	512*	512*
24-hour	651.9	5237.0	160.1	91*	91*
Annual	651.9	5237.0	26.7	15	20

*One exceedance per year is permitted.

The contour plot of annual average SO_2 concentrations for the Little Knife existing PSD Class II scenario is presented in Figure 5-14. Except for the absence of the elevated-concentration pocket at the extreme north end of the Field, which is the result of impact from sources associated with a non-PSD-increment-consuming well, the annual average contour pattern for the existing PSD Class II scenario is virtually identical to the annual average pattern for the existing ambient scenario in Figure 5-13. The difference

Figure 5-14

Little Knife Field
Existing Class II S.
Annual Average SO_2
Conc. ($\mu g/m^3$)



Contour Interval = 1.5
Highest Conc. (+) = 26
PSD Class II Inc. = 15

in overall magnitude of concentrations is attributable to the background concentration (3 $\mu g/m^3$) that was added to complete the ambient results. The observed correspondence between plots was, of course, anticipated because of the absence of any other non-PSD-increment-consuming wells in the Little Knife Field.

Contour plots for all averaging periods for Little Knife existing and future PSD Class II scenario modeling results are included in Appendix C. Again, there is little difference between corresponding plots for existing and future PSD Class II scenarios, suggesting that the additive impact of projected future wells was not very significant for the Little Knife Field.

Because exceedances of allowable increment were predicted for Little Knife PSD Class II scenarios, normalized-composite plots were also prepared. The normalized-composite plot for the existing scenario is provided in Figure 5-15, and the future scenario plot is shown in Figure 5-16. As shown, exceedance areas (100% contour) for both scenarios are very small and localized. Note that some of the exceedance areas in the future scenario have enlarged somewhat over those in the existing scenario. The additional elevated-concentration pockets due to future sources show up better in this type of presentation than in the regular contour plots. However, even for the future scenario, Class II increment exceedances occur in only a small fraction of the total Field area.

5.1.5.3 Terrain Effects

The Little Knife Field is characterized by rolling terrain in the southern and central parts of the Field, which becomes more rugged and defined farther north. Incorporation of terrain effects in the dispersion modeling process would thus affect predicted concentrations in the northern part of the Field more than in the south or central. Even though maximum predicted concentrations are located in the central part of the field, where terrain effects would not be as severe, it is possible that incorporation of terrain effects in the dispersion modeling process would alter ambient predictions to the extent that some AAQS exceedances would be noted. These exceedances would probably, however, be very localized. In any event, as was the case for the Elkhorn Ranch Field, it is not likely that terrain-enhanced impacts would extend into parts of the field where no sources exist.

5.1.6 Lone Butte Field

5.1.6.1 Ambient

Maximum predicted SO_2 concentrations for the Lone Butte Field ambient scenarios are given in Table 5-12. As indicated in Table 5-12, exceedances of the 1-hour and 24-hour AAQS were predicted for both existing and future scenarios. Though still relatively localized, the areal extent of AAQS exceedances for the Lone Butte Field was greater than the very localized exceedances found in other fields (e.g., Elkhorn Ranch). The predicted AAQS exceedances are probably the result of typically high H_2S percentages found in gas from the Lone Butte Field, and the fact that this gas is extensively used to fuel treaters in the Field. In particular, the primary area of exceedance is caused by a horizontal treater with a relatively short stack at well number 9167. Moderate amounts of flaring also occurred early on in the Study period time-frame.

Contour plots of highest 1-hour SO_2 concentrations for the existing and future ambient scenarios are provided in Figures 5-17 and 5-18, respectively. As indicated in the plots, maximum 1-hour concentrations occur in the northern part of the Field, with a secondary maximum area near the middle of the Field. For the future scenario, a third area of elevated 1-hour concentrations (which does not include any AAQS

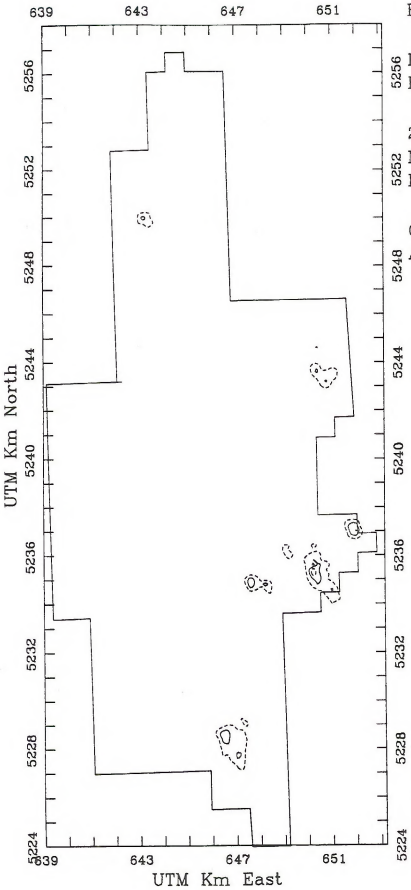


Figure 5-15

Little Knife Field
Existing Class II S.

2nd High SO_2 Conc.
Normalized w.r.t.
PSD Class II Incr.

Composite of All
Averaging Periods

Contour Interval = 20
Contour Units = Percent

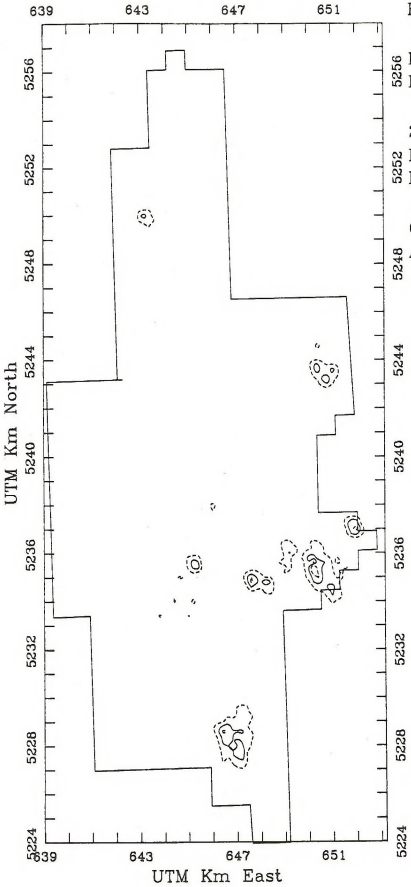


Figure 5-16

Little Knife Field
Future Class II S.

2nd High SO_2 Conc.
Normalized w.r.t.
PSD Class II Incr.

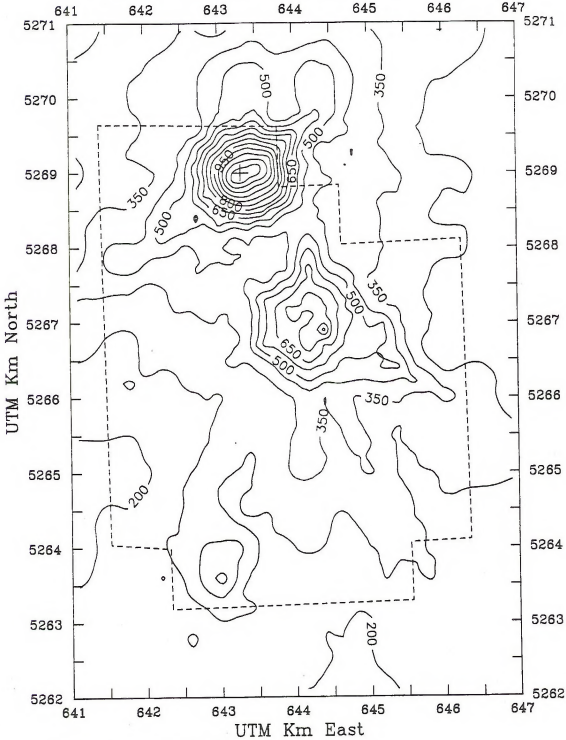
Composite of All
Averaging Periods

Contour Interval = 20
Contour Units = Percent

Figure 5-17

Lone Butte Field - Existing Ambient Scenario

Highest 1-hr SO_2 Concentrations ($\mu g/m^3$)



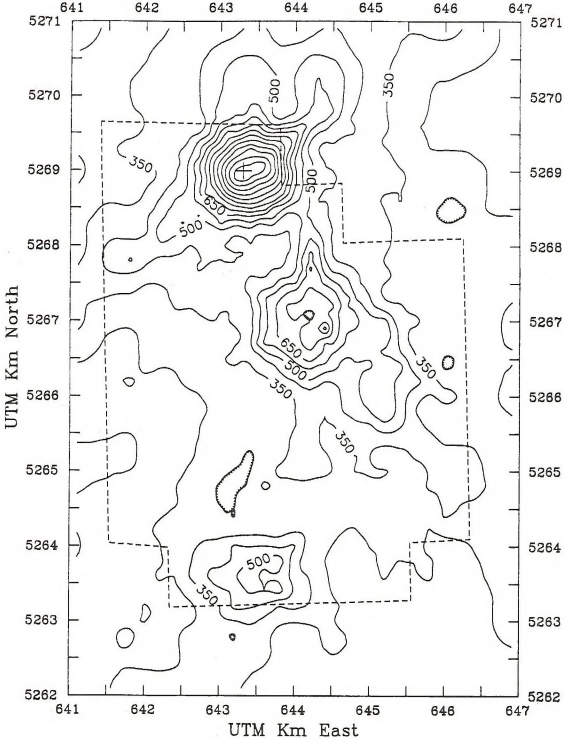
Highest Concentration (+) = 1404

Ambient Air Quality Standard = 715 Contour Interval = 75

Figure 5-18

Lone Butte Field - Future Ambient Scenario

Highest 1-hr SO_2 Concentrations ($\mu g/m^3$)



Highest Concentration (+) = 1405

Ambient Air Quality Standard = 715 Contour Interval = 75

exceedances) is seen in the extreme southern end of the Field. With the exception of this third elevated area, however, 1-hour results for the existing and future scenarios are very similar. As these graphical interpretations would suggest, existing sources are located primarily in the northern part of the Field while future sources are projected to be located in the southern part of the field, and the imposition of projected future sources did not increase the overall maximum concentration. With respect to the areas of elevated concentrations, contour plots for 24-hour and annual averages (Appendix C) demonstrated patterns similar to the plots for 1-hour averages.

TABLE 5-12
Lone Butte Field
Ambient Scenario Modeling Results - SO_2

Averaging Period	Location (UTM km) East	Location (UTM km) North	Predicted Concentration Modeled	Predicted Concentration Background	Predicted Concentration Total	AAQS N.D.	AAQS Federal
Existing Ambient Scenario Highest Predicted Concentrations (μg/m³)							
1-hour	643.3	5269.0	1391.1	13.0	1404.1	715	—
3-hour	643.2	5269.0	1190.8	11.0	1201.8	—	1300*
24-hour	643.3	5269.1	501.3	9.0	510.3	260	365*
Annual	643.3	5269.1	54.1	3.0	57.1	60	80
Future Ambient Scenario Highest Predicted Concentrations (μg/m³)							
1-hour	643.3	5269.0	1391.6	13.0	1404.6	715	—
3-hour	643.2	5269.0	1191.5	11.0	1202.5	—	1300*
24-hour	643.3	5269.1	503.2	9.0	512.2	260	365*
Annual	643.3	5269.1	56.1	3.0	59.1	60	80

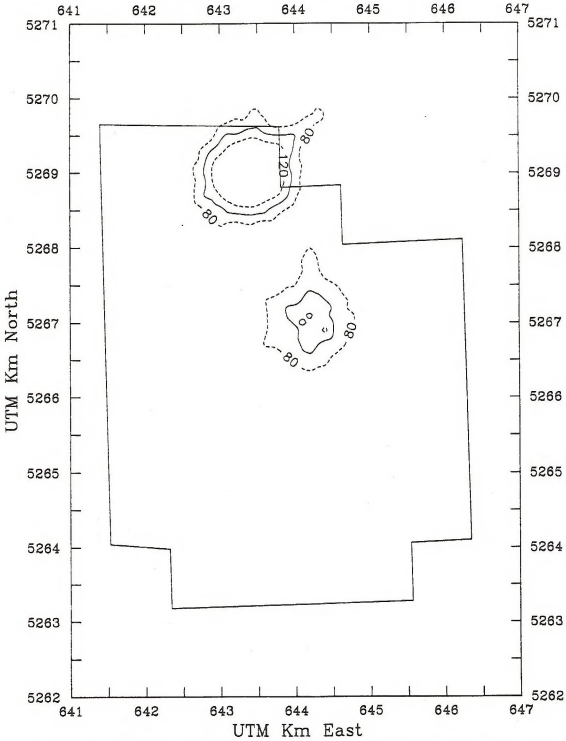
*One exceedance per year is permitted.

Normalized-composite plots for the Lone Butte Field existing and future ambient scenarios are provided in Figures 5-19 and 5-20, respectively. Note that these plots are a composite of the results for 1-hour and 24-hour averages only, because there were no predicted exceedances of 3-hour or annual average AAQS. As expected, the elevated-concentration pockets seen in both the 1-hour and 24-hour results are reflected in the composite plots. These plots also suggest that the imposition of projected future well installations has little effect on model results.

5.1.6.2 PSD Class II

Dispersion modeling results for the Lone Butte Field PSD Class II scenarios are summarized in Table 5-13. As shown in Table 5-13, predicted HSH SO_2 concentrations exceed maximum allowable increments for all three applicable averaging periods. The areal extent of exceedances for the PSD Class II scenarios was significantly greater than for the ambient scenarios, with annual average exceedances for the PSD Class II future scenario covering about one-half of the total Field area. As was the case for the ambient

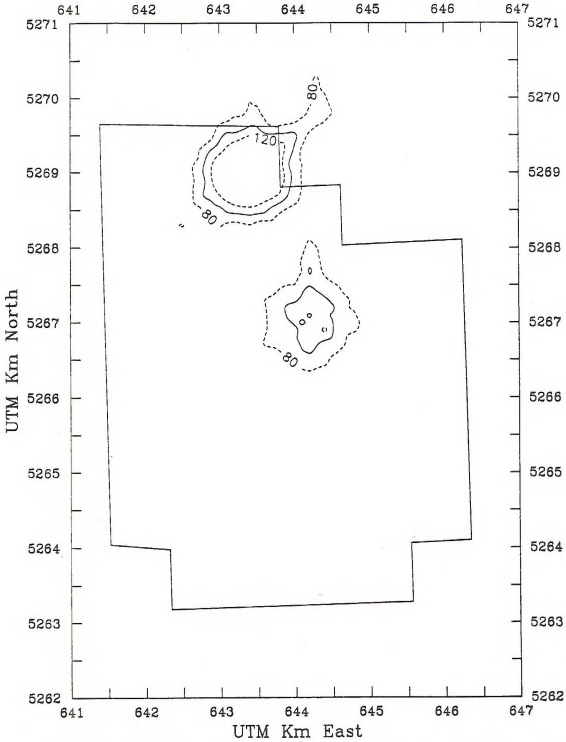
Figure 5-19
Lone Butte Field - Existing Ambient Scenario
Highest SO_2 Conc. Normalized w.r.t. AAQS
Composite of All Averaging Periods



Contour Units = Percent

Contour Interval = 20

Figure 5-20
Lone Butte Field - Future Ambient Scenario
Highest SO_2 Conc. Normalized w.r.t. AAQS
Composite of All Averaging Periods



Contour Units = Percent

Contour Interval = 20

scenario, the imposition of future sources had little effect on PSD Class II scenario results. Again, predicted PSD Class II increment exceedances are probably the result of typically high H_2S percentages found in gas from the Lone Butte Field, and the fact that this gas is extensively used to fuel treaters in the Field.

TABLE 5-13
Lone Butte Field
PSD Class II Scenario Modeling Results - SO_2

Averaging Period	Location (UTM km) East	Location (UTM km) North	Predicted Concentration	Allowable Increment N.D.	Allowable Increment Federal
Existing PSD Class II Scenario Highest 2nd-Highest Predicted Concentrations (μg/m³)					
3-hour	643.4	5268.9	1019.4	512*	512*
24-hour	643.4	5268.8	382.7	91*	91*
Annual	643.3	5269.1	53.7	15	20
Future PSD Class II Scenario Highest 2nd-Highest Predicted Concentrations (μg/m³)					
3-hour	643.4	5268.9	1019.4	512*	512*
24-hour	643.4	5268.8	383.3	91*	91*
Annual	643.3	5269.1	55.7	15	20

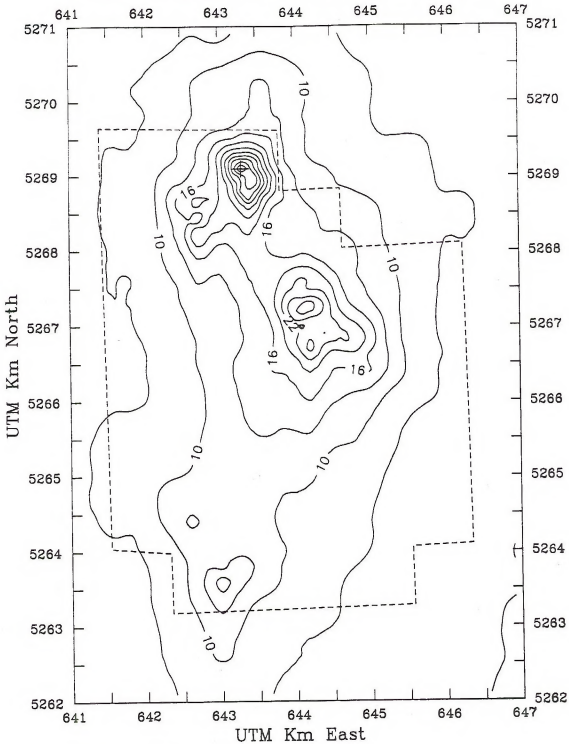
*One exceedance per year is permitted.

The contour plot of predicted annual average SO_2 concentrations for the PSD Class II existing scenario is provided in Figure 5-21, and the plot of predicted annual average SO_2 concentrations for the future scenario is provided in Figure 5-22. With the exception that predicted concentrations for the future scenario are generally about 2 μg/m³ higher than for the existing scenario, the contour patterns for both scenarios appear very similar. Both plots reflect an elevated-concentration pocket associated with the highest concentration in the northern part of the field, and both plots exhibit a secondary area of elevated concentrations near the middle of the Field.

Contour plots for other averaging periods, included in Appendix C for both PSD Class II scenarios, had contour patterns similar to the annual average results portrayed in Figures 5-21 and 5-22. Annual average increment exceedances, however, extended over a much broader portion of the Field than did exceedances of the 3-hour or 24-hour Class II increment.

Normalized-composite plots for the Lone Butte Field existing and future PSD Class II scenarios are provided in Figures 5-23 and 5-24, respectively. Note that the normalized-composite contours are dominated by influence from the annual averaging period (compare Figure 5-23 with Figure 5-21, and Figure 5-24 with Figure 5-22). A comparison of Figure 5-24 with Figure 5-22 reveals that the addition of future sources, projected primarily in the southern part of the field, distinctly increases the areal extent of predicted exceedances of allowable increment.

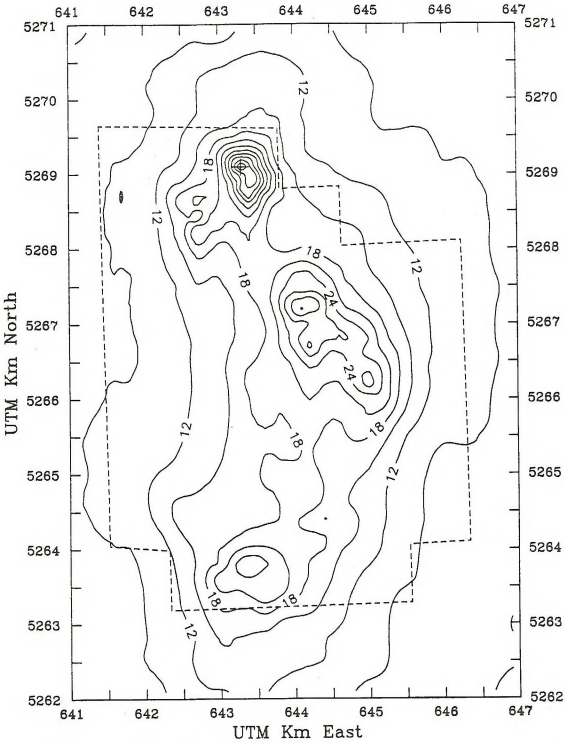
Figure 5-21
Lone Butte Field – Existing PSD Class II Scenario
Annual Average SO_2 Concentrations ($\mu g/m^3$)



Highest Concentration (+) = 54
PSD Class II Increment = 15

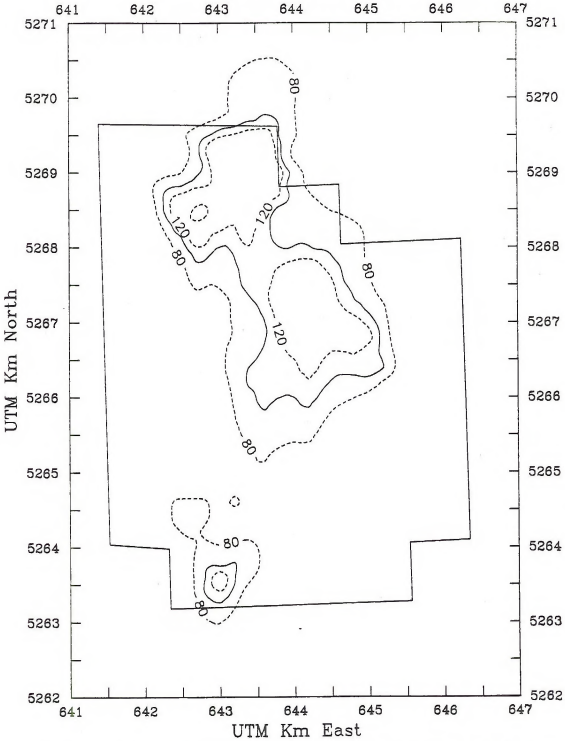
Contour Interval = 3

Figure 5-22
Lone Butte Field – Future PSD Class II Scenario
Annual Average SO_2 Concentrations ($\mu g/m^3$)



Highest Concentration (+) = 56
PSD Class II Increment = 15 Contour Interval = 3

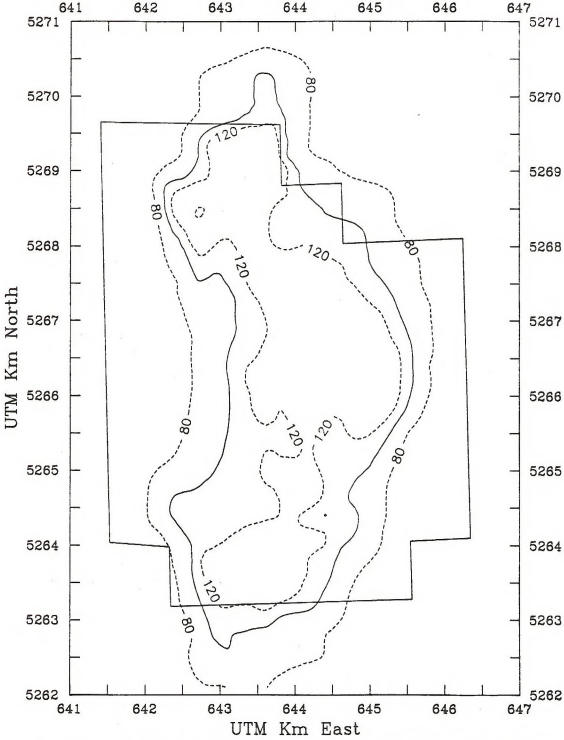
Figure 5-23
Lone Butte Field - Existing PSD Class II Scenario
2nd High SO_2 Conc. Normalized w.r.t. PSD Incr.
Composite of All Averaging Periods



Contour Units = Percent

Contour Interval = 20

Figure 5-24
Lone Butte Field – Future PSD Class II Scenario
2nd High SO_2 Conc. Normalized w.r.t. PSD Incr.
Composite of All Averaging Periods



Contour Units = Percent

Contour Interval = 20

5.1.6.3 Terrain Effects

The Lone Butte Field is characterized with very rugged terrain across the entire field. Incorporation of terrain effects in the dispersion modeling process might have a significant effect on predicted concentrations. The only way to properly assess this effect may be to conduct an additional modeling analysis incorporating sophisticated terrain algorithms and on-site meteorological data if it were possible. It can be concluded, however, that the magnitude of highest concentrations and the areal extent of exceedances would both increase to some degree as a result of the more sophisticated analysis.

5.1.7 Lost Bridge Field

5.1.7.1 Ambient

Maximum predicted SO_2 concentrations for the Lost Bridge Field are summarized in Table 5-14. As indicated in Table 5-14, maximum predicted concentrations exceed AAQS for all four averaging periods for both existing and future scenarios. Even more striking is the magnitude of the maximum predicted concentrations, which exceed AAQS by a factor of 10 for the 1-hour and 24-hour averaging periods. As is the case with other fields, however, the areal extent of AAQS exceedance is very limited, even with the extreme maximums. The high SO_2 concentrations predicted in the Lost Bridge Field are caused exclusively by impact from a relatively high-emitting, short flare associated with the one, and only, existing well (5512). As such, a determination of mitigating measures (see Section 6) will be simplified.

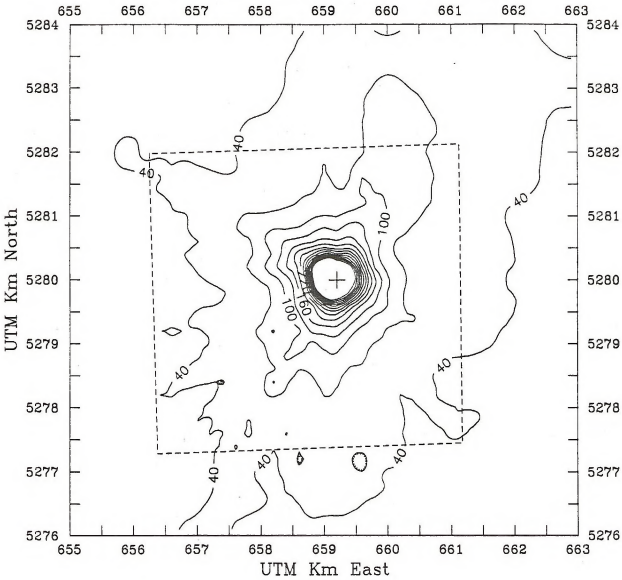
TABLE 5-14
Lost Bridge Field
Ambient Scenario Modeling Results - SO_2

Averaging Period	Location (UTM km) East	Location (UTM km) North	Predicted Concentration Modeled	Predicted Concentration Background	Predicted Concentration Total	AAQS N.D.	AAQS Federal
Existing Ambient Scenario Highest Predicted Concentrations (μg/m³)							
1-hour	659.2	5280.0	7616.9	13.0	7629.9	715	—
3-hour	659.2	5280.0	6584.0	11.0	6595.0	—	1300*
24-hour	659.2	5280.0	2632.1	9.0	2641.1	260	365*
Annual	659.2	5280.0	137.4	3.0	140.4	60	80
Future Ambient Scenario Highest Predicted Concentrations (μg/m³)							
1-hour	659.2	5280.0	7624.9	13.0	7637.9	715	—
3-hour	659.2	5280.0	6599.5	11.0	6610.5	—	1300*
24-hour	659.2	5280.0	2647.1	9.0	2656.1	260	365*
Annual	659.2	5280.0	142.0	3.0	145.0	60	80

*One exceedance per year is permitted.

Highest predicted 24-hour SO_2 concentrations for the existing and future ambient scenarios are plotted in Figures 5-25 and 5-26, respectively. Both plots exhibit a vortex-like pattern of contours which emanate

Figure 5-25
Lost Bridge Field – Existing Ambient Scenario
Highest 24-hr SO_2 Concentrations ($\mu g/m^3$)

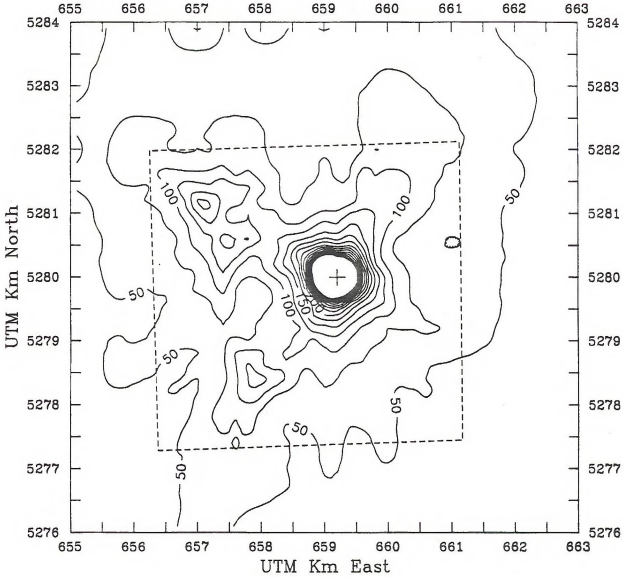


Highest Concentration (+) = 2641
Ambient Air Quality Standard = 260 Contour Interval = 30

Figure 5-26

Lost Bridge Field - Future Ambient Scenario

Highest 24-hr SO_2 Concentrations ($\mu g/m^3$)



Highest Concentration (+) = 2656

Ambient Air Quality Standard = 260 Contour Interval = 25

from the location of the maximum overall 24-hour concentration. Higher-value contours were deleted because of the density of contour spacing. Because of the dominating influence of the existing well, the impact of future wells in Figure 5-26 shows up as relatively minor pockets of elevated concentrations in the western part of the field, and future scenario results overall were very similar to the existing scenario pattern.

Contour plots for other averaging periods for the Lost Bridge ambient scenarios are found in Appendix C. Results for all averaging periods demonstrated the dominating influence of the existing well on model predictions.

Normalized-composite plots for the Lost Bridge Field existing and future ambient scenarios are provided in Figures 5-27 and 5-28, respectively. It is apparent from these plots that, despite the extreme overall maximum concentrations, the areal extent of AAQS exceedances comprises a relatively small part of the field. Also evident from a comparison of Figures 5-27 and 5-28 is the insignificant additive impact of the projected future sources.

5.1.7.2 PSD Class II

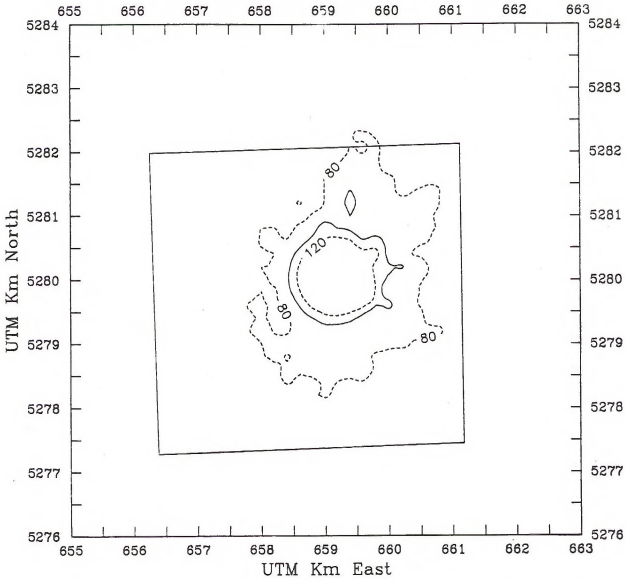
Dispersion modeling results for the Lost Bridge Field PSD Class II scenarios are summarized in Table 5-15. Because the one well installation which dominated predictions for the ambient scenarios does not consume PSD increment, results for the PSD Class II scenarios are very different. As shown in Table 5-15, predicted HSH SO_2 concentrations for the existing scenario are well below allowable increments for each applicable averaging period. The HSH concentrations for the future scenario are below the allowable increment for the 3-hour averaging period, but exceed allowable increments for the 24-hour and annual averages. Predicted concentrations for the existing scenario are low because impact is due entirely to sources located outside of the subject Field.

TABLE 5-15
Lost Bridge Field
PSD Class II Scenario Modeling Results - SO_2

Averaging Period	Location (UTM km) East	Location (UTM km) North	Predicted Concentration	Allowable Increment N.D.	Allowable Increment Federal
Existing PSD Class II Scenario Highest 2nd-Highest Predicted Concentrations (μg/m³)					
3-hour	656.2	5278.0	34.6	512*	512*
24-hour	656.2	5279.8	9.6	91*	91*
Annual	656.2	5280.8	1.4	15	20
Future PSD Class II Scenario Highest 2nd-Highest Predicted Concentrations (μg/m³)					
3-hour	657.2	5281.0	451.5	512*	512*
24-hour	657.2	5281.0	164.6	91*	91*
Annual	657.2	5281.2	20.2	15	20

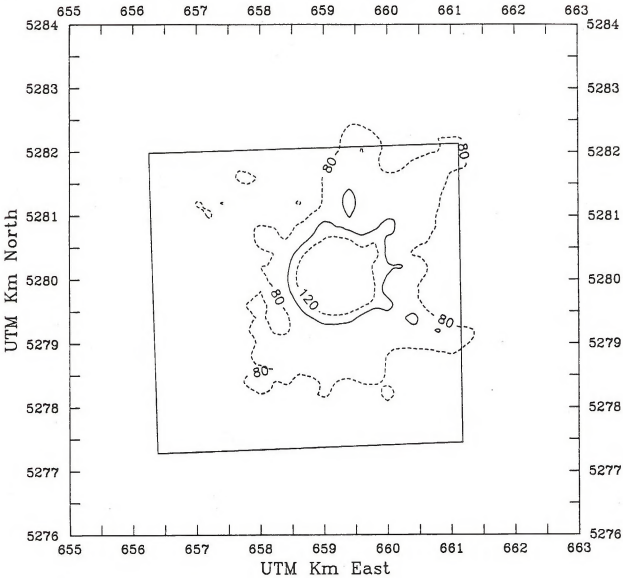
*One exceedance per year is permitted.

Figure 5-27
Lost Bridge Field - Existing Ambient Scenario
Highest SO_2 Conc. Normalized w.r.t. AAQS
Composite of All Averaging Periods



Contour Units = Percent Contour Interval = 20

Figure 5-28
Lost Bridge Field – Future Ambient Scenario
Highest SO_2 Conc. Normalized w.r.t. AAQS
Composite of All Averaging Periods



Contour Units = Percent Contour Interval = 20

Again, the appearance of contour plots for the Lost Bridge PSD Class II scenarios was very different from the plots for the ambient scenarios. Second-highest predicted 24-hour SO_2 concentrations for the future scenario are plotted in Figure 5-29. As shown, elevated-concentration pockets tend to reflect the locations of future wells (Appendix B) which are located in the western part of the Field. Contour patterns for 3-hour and annual average plots for the future scenario (Appendix C) were similar to the 24-hour results. Contour patterns for existing scenario plots (Appendix C) were erratic and ill-defined because impact was due entirely to sources located outside the Field.

The normalized-composite plot for the Lost Bridge Field future PSD Class II scenario is provided in Figure 5-30 (a normalized-composite plot was not prepared for the existing scenario because no exceedances of allowable increment were predicted). As shown, the area of increment exceedance tends to be localized in the vicinity of projected future wells. Overall, the areal extent of predicted exceedance comprises a relatively small fraction of total field area.

5.1.7.3 Terrain Effects

Terrain in the Lost Bridge Field is typically rugged, but terrain height variations are not so severe as seen in the Lone Butte Field. Because predicted concentrations already greatly exceed AAQS, incorporation of terrain effects in the dispersion modeling procedure would not meaningfully change results for the Lost Bridge ambient scenarios. Highest second-highest predicted concentrations for the PSD Class II existing scenario would likely remain well below allowable increments if terrain was addressed. However, consideration of terrain could affect PSD Class II results for the future scenario to the extent that the 3-hour average increment might also be exceeded (i.e., in addition to the 24-hour and annual exceedances).

5.1.8 Rough Rider Field

5.1.8.1 Ambient

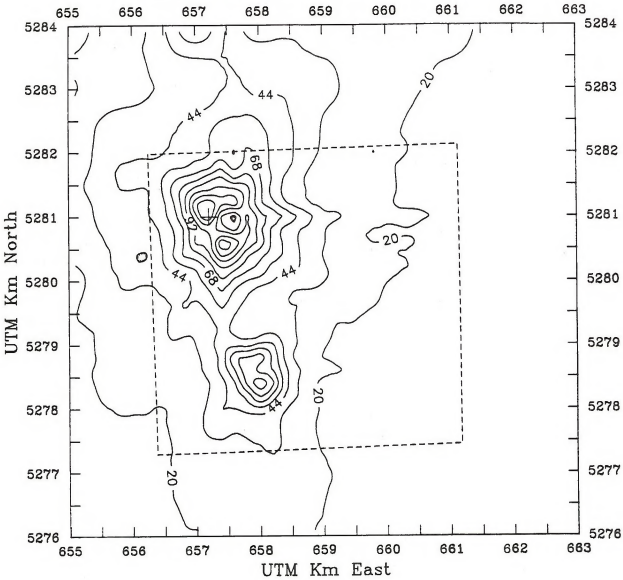
Maximum predicted SO_2 concentrations for the Rough Rider Field are listed in Table 5-16. Maximum predicted concentrations, as shown in Table 5-16, exceed AAQS for all applicable averaging periods for both existing and future scenarios. As was the case for the Lost Bridge Field, the magnitude of the maximum predictions for the Rough Rider Field is striking. In fact, maximum predicted concentrations for the Rough Rider ambient scenarios were the highest of all Study Fields. But again, despite the extreme maximum concentrations, the areal extent of exceedances for the Rough Rider Field included only a small fraction of total Field area. High predicted concentrations are probably due to moderately high H_2S percentages coupled with relatively high well density in the central part of the Field where maximum predictions were found. However, the extreme concentrations are due to the impact of a relatively high-emitting, ground-level flare at well number 11817.

Contour plots of highest predicted 24-hour SO_2 concentrations for the Rough Rider existing and future ambient scenarios are provided in Figures 5-31 and 5-32, respectively. Note that the contour interval for the future scenario plot is twice as large as the interval for the existing scenario plot. In both plots, the localized area of AAQS exceedances associated with the location of the maximum predicted concentration is apparent in the south-central part of the field. In comparing Figure 5-32 with Figure 5-31, it is evident that, despite the similarity of overall maximum predicted concentrations, the addition of projected future wells has a significant effect on dispersion model results. Highest predicted 24-hour concentrations in general are significantly higher for the future scenario, as depicted by the contour labeling. Also, numerous additional elevated-concentration pockets associated with future wells are visible in the north-central part of the Field in the future scenario plot.

Figure 5-29

Lost Bridge Field - Future PSD Class II Scenario

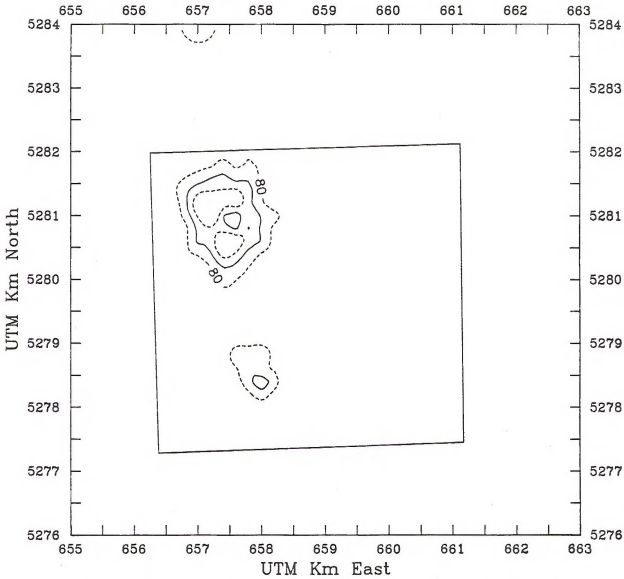
Second Highest 24-hr SO_2 Conc. ($\mu g/m^3$)



Highest 2nd Highest Concentration (+) = 165

PSD Class II Increment = 91 Contour Interval = 12

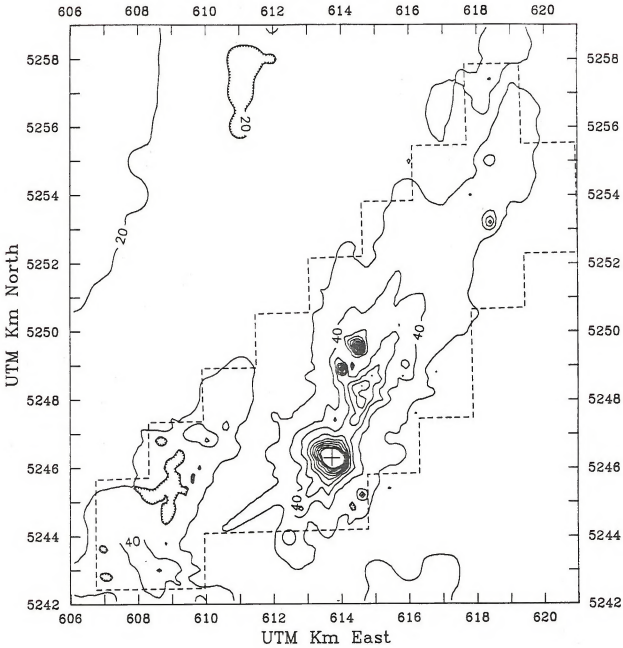
Figure 5-30
Lost Bridge Field - Future PSD Class II Scenario
2nd High SO_2 Conc. Normalized w.r.t. PSD Incr.
Composite of All Averaging Periods



Contour Units = Percent

Contour Interval = 20

Figure 5-31
Rough Rider Field - Existing Ambient Scenario
Highest 24-hr SO_2 Concentrations ($\mu g/m^3$)

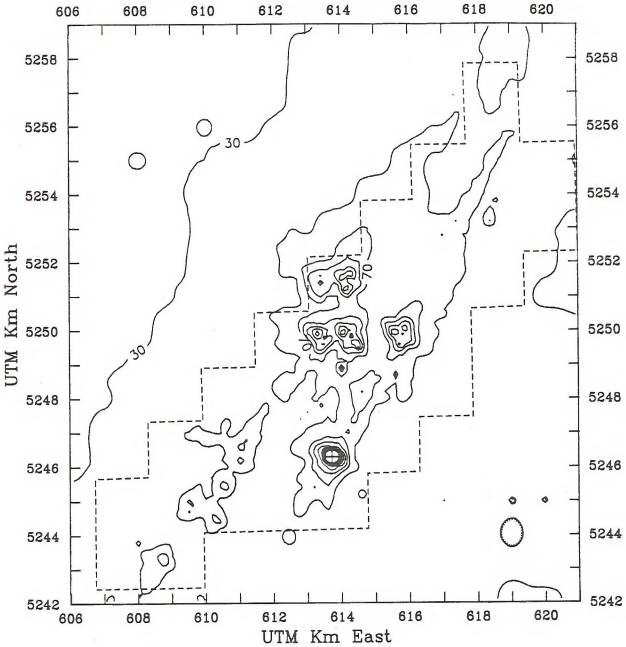


Highest Concentration (+) = 2918
Ambient Air Quality Standard = 260 Contour Interval = 10

Figure 5-32

Rough Rider Field – Future Ambient Scenario

Highest 24-hr SO_2 Concentrations ($\mu g/m^3$)



Highest Concentration (+) = 2922

Ambient Air Quality Standard = 260 Contour Interval = 20

TABLE 5-16
Rough Rider Field
Ambient Scenario Modeling Results - SO_2

Averaging Period	Location (UTM km) East	Location (UTM km) North	Predicted Concentration Modeled	Predicted Concentration Background	Predicted Concentration Total	AAQS N.D.	AAQS Federal
Existing Ambient Scenario Highest Predicted Concentrations (μg/m³)							
1-hour	613.7	5246.3	10800	13	10813	715	—
3-hour	613.7	5246.3	5634	11	5645	—	1300*
24-hour	613.7	5246.3	2909	9	2918	260	365*
Annual	613.7	5246.3	163	3	166	60	80
Future Ambient Scenario Highest Predicted Concentrations (μg/m³)							
1-hour	613.7	5246.3	10803	13	10816	715	—
3-hour	613.7	5246.3	5641	11	5652	—	1300*
24-hour	613.7	5246.3	2913	9	2922	260	365*
Annual	613.7	5246.3	167	3	170	60	80

*One exceedance per year is permitted.

Existing and future ambient scenario contour plots for 1-hour and annual averaging periods are found in Appendix C. These plots exhibited patterns similar to the 24-hour results in Figures 5-31 and 5-32, including the location of the overall maximum concentration in the south-central part of the field, and the tendency for the addition of future wells to have a significant effect on results.

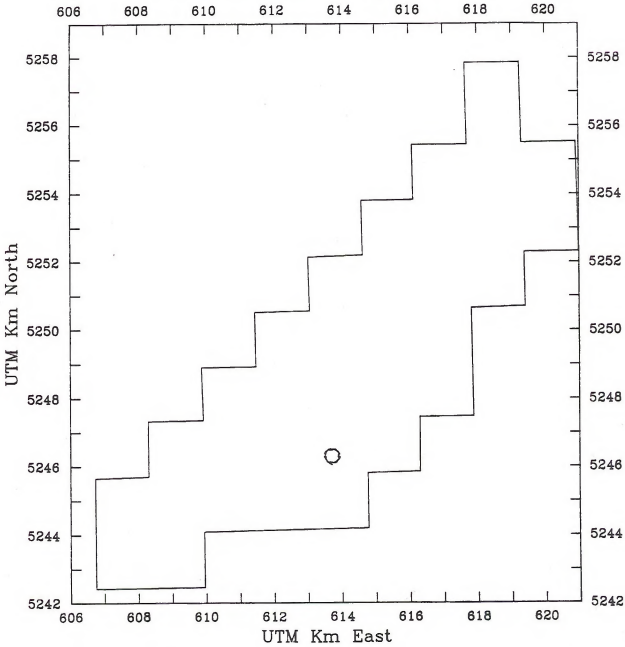
Normalized-composite plots for the Rough Rider Field existing and future ambient scenarios are provided in Figures 5-33 and 5-34, respectively. It is again apparent from these normalized-composite plots that the areal extent of AAQS exceedances is very limited, comprising only a small fraction of total Field area. Also evident from a comparison of Figures 5-33 and 5-34 is the impact of the addition of future wells.

5.1.8.1 PSD Class II

Dispersion modeling results for the Rough Rider Field PSD Class II scenarios are summarized in Table 5-17. As shown in Table 5-17, predicted HSH SO_2 concentrations greatly exceed allowable increments for each applicable averaging period. Predicted HSH concentrations for the Rough Rider PSD Class II scenarios were the highest for all Study fields. The areal extent of exceedances was limited, but was notably larger than for the corresponding (existing and future) ambient scenarios. Again, the extreme predictions were due to the impact of a single ground-level flare.

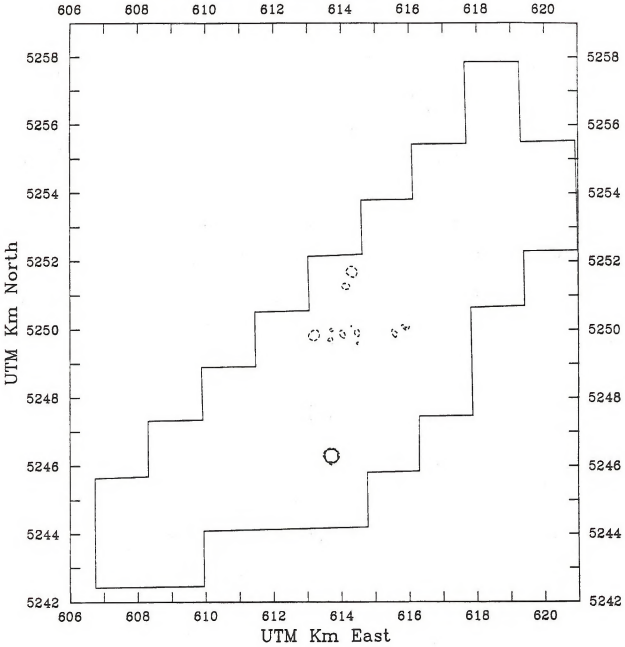
Second-highest predicted 3-hour SO_2 concentrations for the Rough Rider existing and future PSD Class II scenarios are plotted in Figures 5-35 and 5-36, respectively. As in the Rough Rider ambient scenarios, Figures 5-35 and 5-36 reveal that the HSH concentration for the PSD Class II scenarios is located in the south-central part of the field, and that the imposition of projected future sources has a significant effect on dispersion model results. The existing and future scenario contour plots for 24-hour and annual

Figure 5-33
Rough Rider Field – Existing Ambient Scenario
Highest SO_2 Conc. Normalized w.r.t. AAQS
Composite of All Averaging Periods



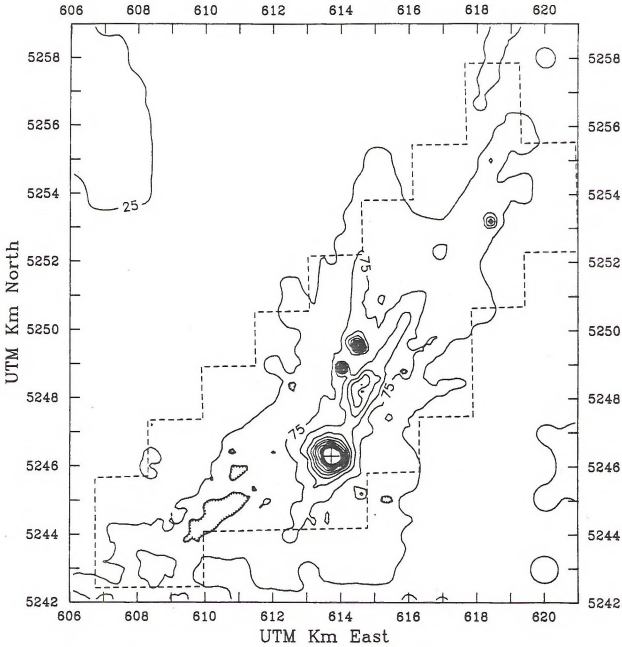
Contour Units = Percent Contour Interval = 20

Figure 5-34
Rough Rider Field - Future Ambient Scenario
Highest SO_2 Conc. Normalized w.r.t. AAQS
Composite of All Averaging Periods



Contour Units = Percent Contour Interval = 20

Figure 5-35
Rough Rider Field – Existing PSD Class II Scenario
Second Highest 3-hr SO_2 Conc. ($\mu g/m^3$)

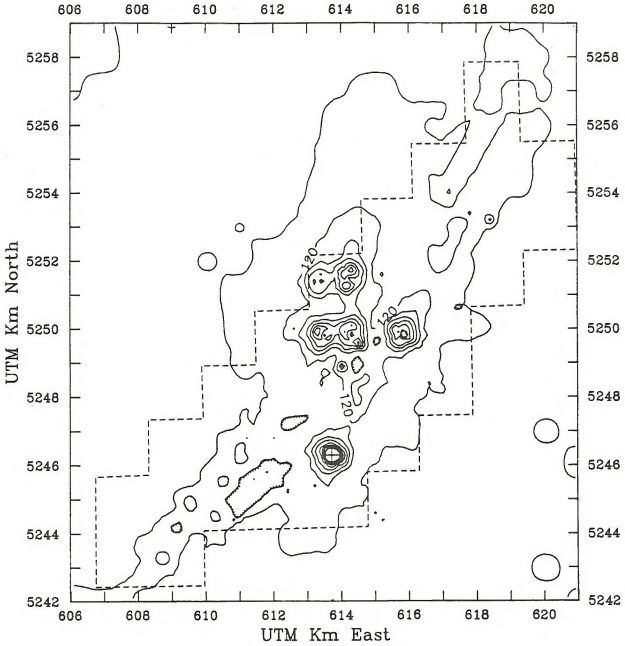


Highest 2nd Highest Concentration (+) = 5607
PSD Class II Increment = 512 Contour Interval = 25

Figure 5-36

Rough Rider Field - Future PSD Class II Scenario

Second Highest 3-hr SO_2 Conc. ($\mu g/m^3$)



Highest 2nd Highest Concentration (+) = 5609

PSD Class II Increment = 512 Contour Interval = 40

averaging periods (found in Appendix C) also shared these characteristics, and exhibited generally similar contour patterns for corresponding scenarios.

TABLE 5-17
Rough Rider Field
PSD Class II Scenario Modeling Results - SO_2

Averaging Period	Location (UTM km) East	Location (UTM km) North	Predicted Concentration	Allowable Increment N.D.	Allowable Increment Federal
Existing PSD Class II Scenario Highest 2nd-Highest Predicted Concentrations (μg/m³)					
3-hour	613.7	5246.3	5607	512*	512*
24-hour	613.7	5246.3	1891	91*	91*
Annual	613.7	5246.3	163	15	20
Future PSD Class II Scenario Highest 2nd-Highest Predicted Concentrations (μg/m³)					
3-hour	613.7	5246.3	5609	512*	512*
24-hour	613.7	5246.3	1898	91*	91*
Annual	613.7	5246.3	167	15	20

*One exceedance per year is permitted.

The normalized-composite plots for the Rough Rider Field existing and future PSD Class II scenarios are provided in Figures 5-37 and 5-38, respectively. As shown in Figure 5-37, the areal extent of increment exceedance for the existing scenario is very limited. In comparing Figure 5-38 with Figure 5-37, however, it is apparent that the addition of projected future wells greatly increases the areal extent of exceedance in the center of the Field, and creates additional pockets of elevated concentrations through the southwest end of the Field.

5.1.8.3 Terrain Effects

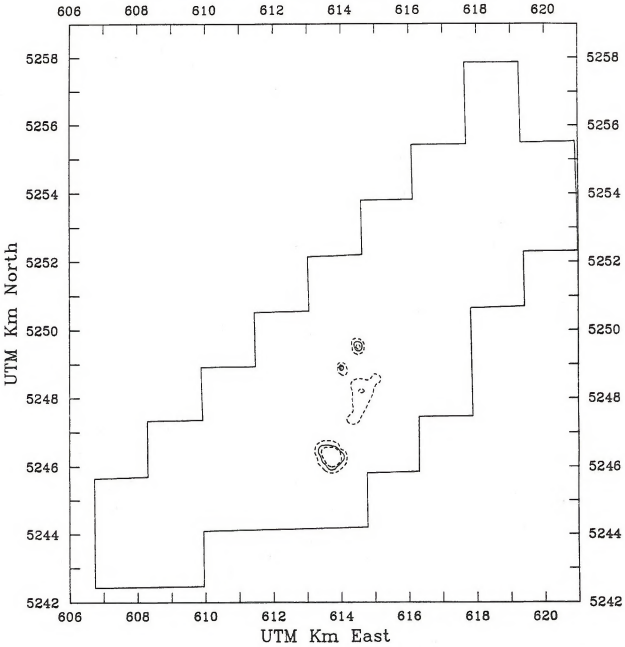
Terrain in the Rough Rider Field is typically rugged, and incorporation of terrain effects in the dispersion modeling procedure would likely affect model results for this Field to some extent. Given that predicted concentrations for all scenarios already greatly exceed applicable AAQS or allowable increments for all averaging periods, consideration of terrain effects would not meaningfully affect results in the context of the highest predicted concentration. Inclusion of terrain effects, however, could expand the areal extent of predicted exceedances.

5.1.9 Scairt Woman Field

5.1.9.1 Ambient

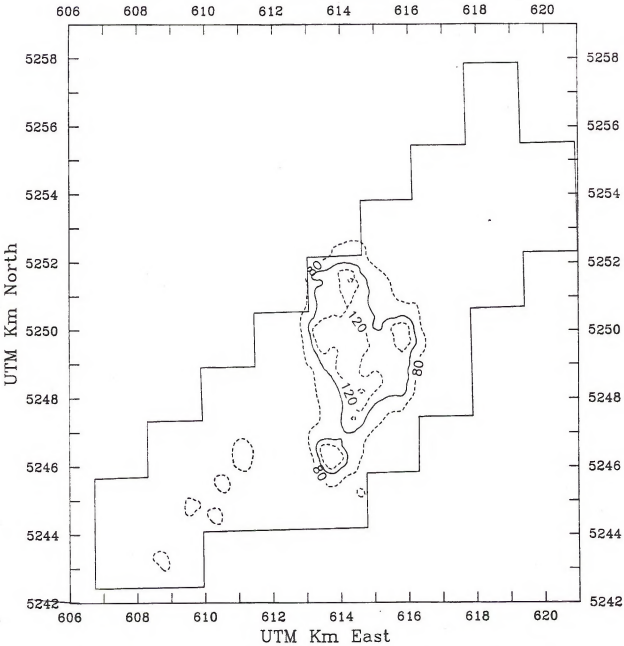
Maximum predicted SO_2 concentrations for the Scairt Woman Field ambient scenarios are summarized in Table 5-18. As shown, maximum concentrations for the existing scenario are below AAQS for each

Figure 5-37
Rough Rider Field - Existing PSD Class II Scenario
2nd High SO_2 Conc. Normalized w.r.t. PSD Incr.
Composite of All Averaging Periods



Contour Units = Percent Contour Interval = 20

Figure 5-38
Rough Rider Field – Future PSD Class II Scenario
2nd High SO_2 Conc. Normalized w.r.t. PSD Incr.
Composite of All Averaging Periods



Contour Units = Percent Contour Interval = 20

applicable averaging period. Maximum predicted concentrations for the future scenario exceed AAQS for 1-hour and 24-hour averages, and are within AAQS for 3-hour and annual averaging periods. The areal extent of exceedances of 1-hour and 24-hour AAQS for the future scenario are extremely limited. Results are significantly different between the existing and future scenarios because the Field includes only one existing well, while several future wells were projected. Because only one existing well is present in the Field, the future scenario exceedances are likely due primarily to the impact of projected future wells.

TABLE 5-18
Scairt Woman Field
Ambient Scenario Modeling Results - SO_2

Averaging Period	Location (UTM km) East	Location (UTM km) North	Predicted Concentration Modeled	Predicted Concentration Background	Predicted Concentration Total	AAQS N.D.	AAQS Federal
Existing Ambient Scenario Highest Predicted Concentrations (μg/m³)							
1-hour	624.6	5244.0	324.4	13.0	337.4	715	—
3-hour	625.0	5244.4	220.1	11.0	231.1	—	1300*
24-hour	625.0	5244.4	108.6	9.0	117.6	260	365*
Annual	625.0	5244.2	10.3	3.0	13.3	60	80
Future Ambient Scenario Highest Predicted Concentrations (μg/m³)							
1-hour	626.2	5245.3	894.5	13.0	907.5	715	—
3-hour	626.7	5245.2	640.8	11.0	651.8	—	1300*
24-hour	626.7	5245.2	274.4	9.0	283.4	260	365*
Annual	626.4	5244.8	25.8	3.0	28.8	60	80

*One exceedance per year is permitted.

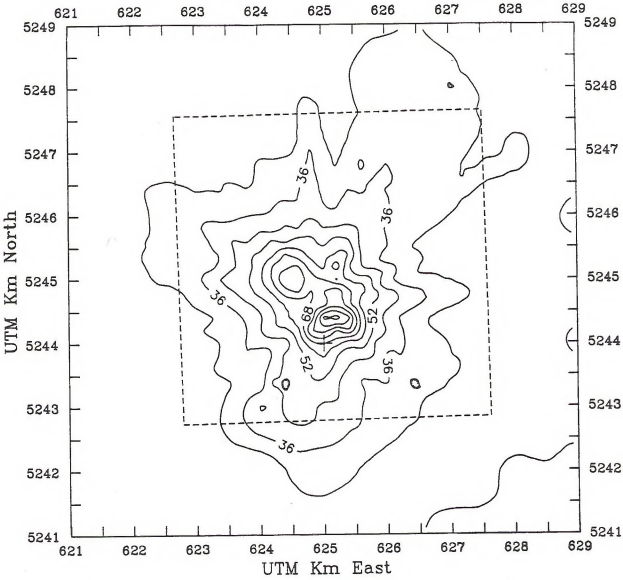
Highest 24-hour SO_2 concentrations for the Scairt Woman existing ambient scenario are plotted in Figure 5-39, and highest 24-hour concentrations for the future ambient scenario are plotted in Figure 5-40. Significant differences between modeling results for the existing and future scenarios become apparent upon comparison of Figures 5-39 and 5-40. Highest predicted concentrations throughout the field are significantly larger for the future scenario. The location of the maximum overall concentration changes between scenarios. The maximum 24-hour concentration for the existing scenario is located in the south-central part of the Field near the single existing well (6959), while the maximum 24-hour concentration for the future scenario is located in the east-central part of the Field near a pair of future wells (F6, F7). The contour pattern for both scenarios appears to be largely influenced by the location of the overall maximum concentration.

The location of the maximum concentration and the general contour pattern for other averaging periods are similar to the 24-hour results for corresponding existing and future scenarios. Contour plots for the other averaging periods are included in Appendix C.

Figure 5-39

Scairt Woman Field - Existing Ambient Scenario

Highest 24-hr SO_2 Concentrations ($\mu g/m^3$)



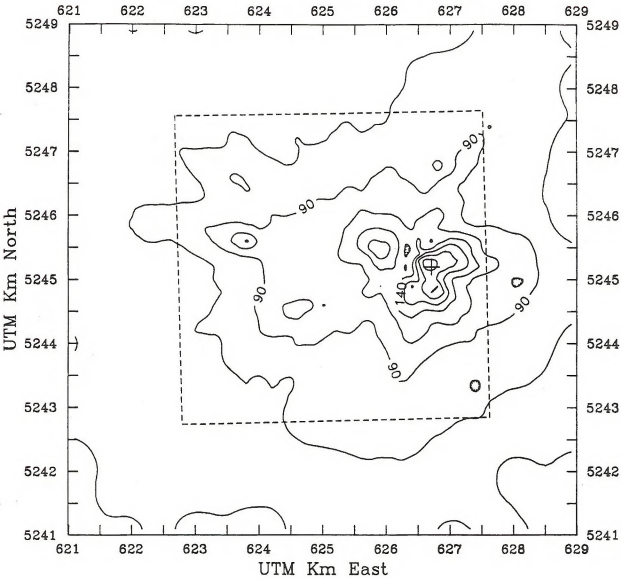
Highest Concentration (+) = 118

Ambient Air Quality Standard = 260 Contour Interval = 8

Figure 5-40

Scairt Woman Field – Future Ambient Scenario

Highest 24-hr SO_2 Concentrations ($\mu g/m^3$)



Highest Concentration (+) = 283

Ambient Air Quality Standard = 260 Contour Interval = 25

The normalized-composite plot for the Scairt Woman Field future ambient scenario is provided in Figure 5-41 (a normalized-composite plot was not prepared for the existing scenario because no exceedances were predicted). The normalized-composite plot illustrates the very localized nature of the exceedance area, and the likelihood that the highest predicted concentrations were due primarily to impact from sources associated with future wells (F6, F7).

5.1.9.2 PSD Class II

Dispersion modeling results for the Scairt Woman Field PSD Class II scenarios are summarized in Table 5-19. As shown in Table 5-19, predicted HSH SO_2 concentrations are below allowable increments for each applicable averaging period for the existing scenario, but exceed allowable increments for each applicable averaging period for the future scenario. Differences in predicted results between the two scenarios are due to the presence of only one existing well versus several projected future wells in the Field. Future scenario exceedances of allowable increment are due primarily to the impact of projected future wells.

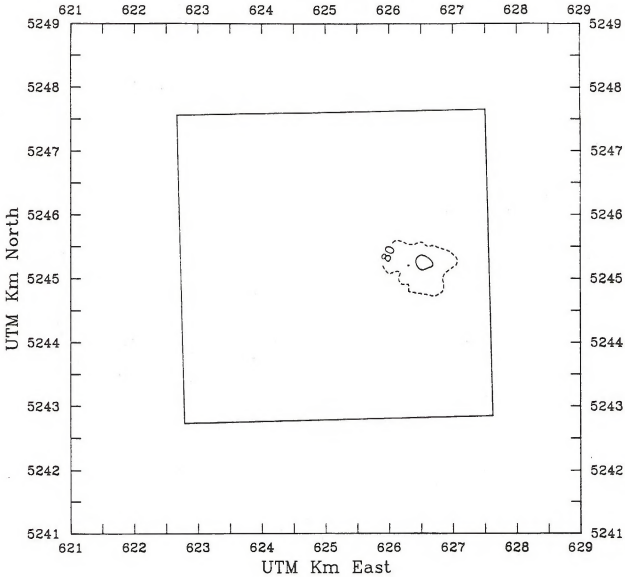
TABLE 5-19
Scairt Woman Field
PSD Class II Scenario Modeling Results - SO_2

Averaging Period	Location (UTM km) East	Location (UTM km) North	Predicted Concentration	Allowable Increment N.D.	Allowable Increment Federal
Existing PSD Class II Scenario Highest 2nd-Highest Predicted Concentrations (µg/m³)					
3-hour	625.0	5244.4	207.0	512*	512*
24-hour	625.0	5244.4	77.2	91*	91*
Annual	625.0	5244.2	10.2	15	20
Future PSD Class II Scenario Highest 2nd-Highest Predicted Concentrations (µg/m³)					
3-hour	626.7	5245.2	599.0	512*	512*
24-hour	626.7	5245.2	225.9	91*	91*
Annual	626.4	5244.8	25.6	15	20

*One exceedance per year is permitted.

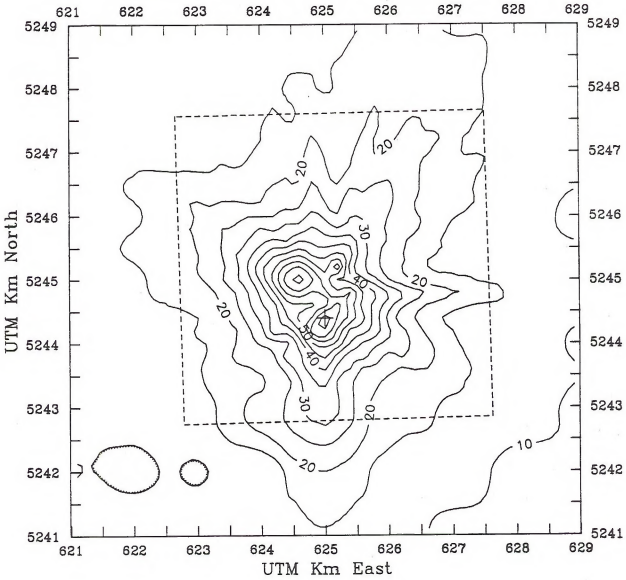
Because the Scairt Woman Field did not include any non-PSD-increment-consuming sources, modeling results and plotted contour patterns were very similar between corresponding ambient and PSD Class II scenarios. Contour plots of 24-hour results for the PSD Class II existing and future scenarios are provided in Figures 5-42 and 5-43, respectively. The only reason that results presented in Figures 5-42 and 5-43 differ from the respective Figures 5-39 and 5-40 is that one set is portraying highest predicted concentrations (ambient scenarios) while the other is portraying second-highest predictions (PSD Class

Figure 5-41
Scairt Woman Field - Future Ambient Scenario
Highest SO_2 Conc. Normalized w.r.t. AAQS
Composite of All Averaging Periods



Contour Units = Percent Contour Interval = 20

Figure 5-42
Scairt Woman Field - Existing PSD Class II Scen.
Second Highest 24-hr SO_2 Conc. ($\mu g/m^3$)

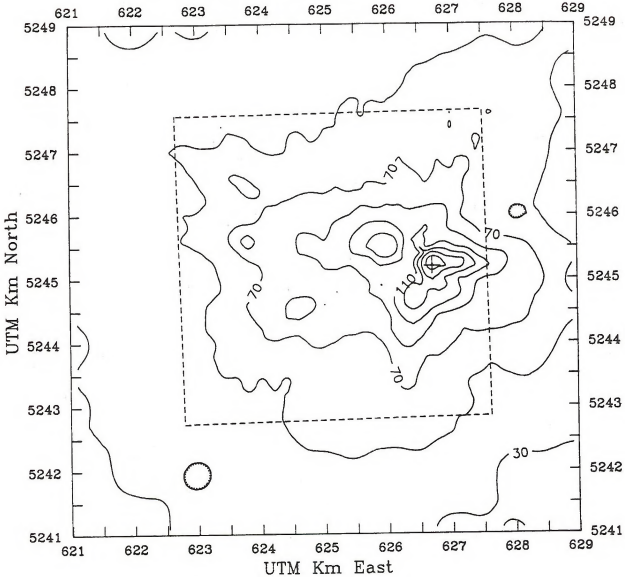


Highest 2nd Highest Concentration (+) = 77
PSD Class II Increment = 91 Contour Interval = 5

Figure 5-43

Scairt Woman Field - Future PSD Class II Scen.

Second Highest 24-hr SO_2 Conc. ($\mu g/m^3$)



Highest 2nd Highest Concentration (+) = 226

PSD Class II Increment = 91 Contour Interval = 20

II scenarios). Model input data were identical. The PSD Class II results also reflect overall highest concentrations for the existing scenario in the south-central part of the Field, and overall highest concentrations for the future scenario in the east-central part of the Field. Contour plots for other averaging periods for the Scairt Woman PSD Class II scenarios can be found in Appendix C.

The normalized-composite plot for the Scairt Woman Field future PSD Class II scenario is provided in Figure 5-44 (a normalized-composite plot was not prepared for the existing scenario because no exceedances were predicted). Note that the total area of exceedance is relatively large compared to the size of the Field. Figure 5-44 suggests that the addition of projected future wells to the Scairt Woman Field will have a very significant impact on PSD Class II increments.

5.1.9.3 Terrain Effects

Terrain in the vicinity of the Scairt Woman Field is generally very rugged. However, the existing well and projected future wells tend to be located in regions of relatively high elevation within the Field. Therefore, the effect of terrain on dispersion modeling results would probably not be as significant as suggested for other Study fields with rugged terrain (e.g., Lone Butte, Lost Bridge). However, incorporation of terrain effects could still increase predicted concentrations to the extent that limited exceedances might be seen for 24-hour and annual averaging periods for the existing PSD Class II scenario.

5.1.10 Smith Field

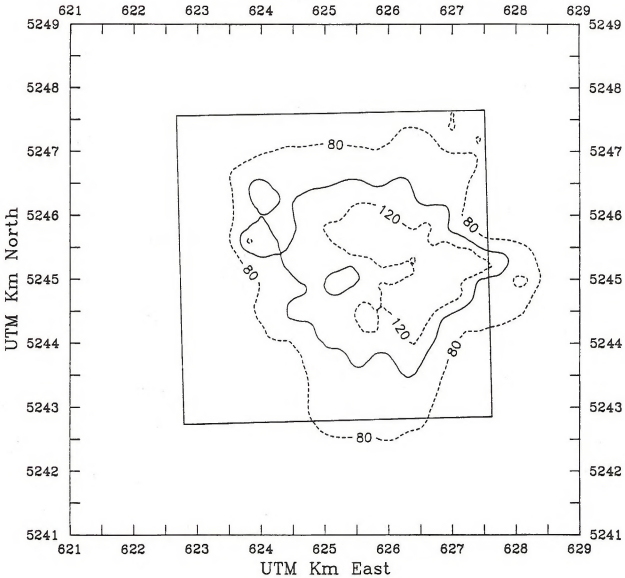
5.1.10.1 Ambient

The overall highest predicted SO_2 concentrations for the Smith Field ambient scenarios are provided in Table 5-20. As indicated in Table 5-20, maximum predicted concentrations are below AAQS for each applicable averaging period for both existing and future scenarios. Maximum predicted concentrations for the future scenario are very similar to those for the existing scenario for corresponding averaging periods, which suggests that the addition of projected future wells to the Field will cause little additional air quality degradation. Actually, relatively high predicted concentrations could have been expected because the Smith Field has no gas-gathering system (i.e., all gas is used for treater fuel or flared). Maximum predicted concentrations probably remained below AAQS, however, because well density is low, and relatively tall stacks are used with both treaters and flares.

Highest predicted 1-hour SO_2 concentrations for the Smith Field existing and future ambient scenarios are plotted in Figures 5-45 and 5-46, respectively. The similarity in results for the existing and future scenarios is evident from a comparison of these plots. Minor pockets of elevated concentrations associated with future well installations located in the northeast (well F1) and extreme southern (well F3) parts of the Field are detectable in the future scenario plot. But, on balance, 1-hour contour patterns for both scenarios are very similar. This similarity was also seen in the contour plots for other averaging periods, which are included in Appendix C.

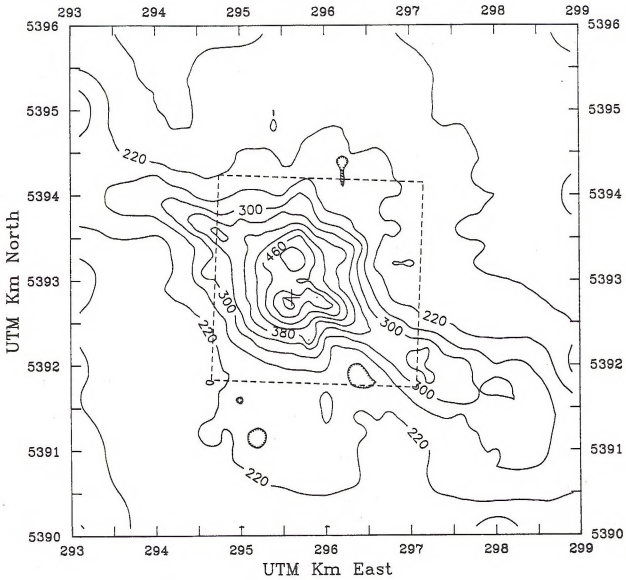
Figure 5-44

Scairt Woman Field – Future PSD Class II Scenario
2nd High SO_2 Conc. Normalized w.r.t. PSD Incr.
Composite of All Averaging Periods



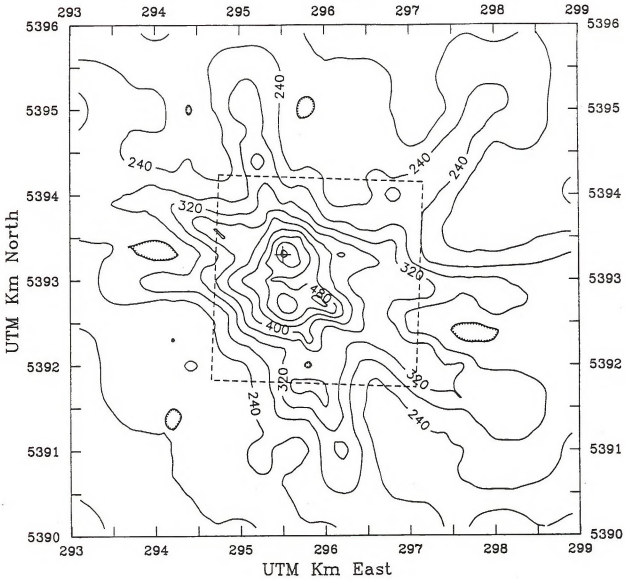
Contour Units = Percent Contour Interval = 20

Figure 5-45
Smith Field - Existing Ambient Scenario
Highest 1-hr SO_2 Concentrations ($\mu g/m^3$)



Highest Concentration (+) = 626
Ambient Air Quality Standard = 715 Contour Interval = 40

Figure 5-46
Smith Field - Future Ambient Scenario
Highest 1-hr SO_2 Concentrations ($\mu g/m^3$)



Highest Concentration (+) = 670
Ambient Air Quality Standard = 715 Contour Interval = 40

TABLE 5-20
Smith Field
Ambient Scenario Modeling Results - SO_2

Averaging Period	Location (UTM km)** East	North	Predicted Concentration Modeled	Background	Total	AAQS N.D.	Federal
Existing Ambient Scenario Highest Predicted Concentrations (μg/m³)							
1-hour	295.6	5392.8	612.5	13.0	625.5	715	—
3-hour	295.6	5392.7	451.5	11.0	462.5	—	1300*
24-hour	295.6	5392.7	188.4	9.0	197.4	260	365*
Annual	295.6	5392.8	26.0	3.0	29.0	60	80
Future Ambient Scenario Highest Predicted Concentrations (μg/m³)							
1-hour	295.5	5393.3	657.3	13.0	670.3	715	—
3-hour	295.6	5392.7	451.5	11.0	462.5	—	1300*
24-hour	295.6	5392.8	189.9	9.0	198.9	260	365*
Annual	295.6	5392.8	30.3	3.0	33.3	60	80

*One Exceedance per year is permitted.
**UTM Zone 14

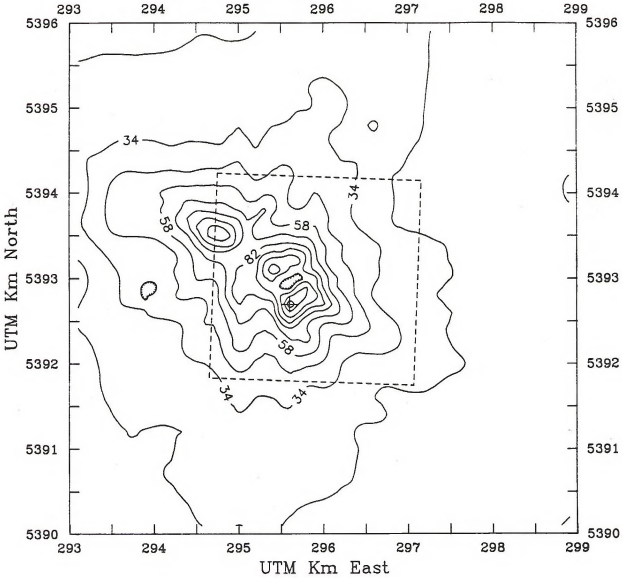
5.1.10.2 PSD Class II

Dispersion modeling results for the Smith Field PSD Class II scenarios are summarized in Table 5-21. As shown, predicted HSH concentrations are below allowable increments for the 3-hour averaging period, but exceed allowable increments for the 24-hour and annual averaging periods, for both existing and future scenarios. The similarity in the Table 5-21 results between the existing and future scenarios suggests that the addition of projected future sources to the field will cause little additional air quality degradation with respect to Class II increment, and that predicted exceedances for both scenarios are primarily the result of impact from sources associated with existing wells.

Despite the similarity in predicted HSH concentrations, however, normalized-composite plots (below) reveal that the PSD increment exceedance area is greatly expanded for the future scenario compared to the existing scenario. The 24-hour and annual average PSD increment exceedances for both scenarios are probably due to the lack of a gas-gathering system in the Field.

A contour plot of predicted second-highest 24-hour concentrations for the Smith Field existing PSD Class II scenario is provided in Figure 5-47, and a plot of predicted second-highest 24-hour concentrations for the future PSD Class II scenario is provided in Figure 5-48. Note that highest overall concentrations for both scenarios are located in approximately the middle of the field, near existing wells. Additional elevated-concentration pockets associated with future wells in the east and south parts of the Field are clearly evident in the future scenario plot (Figure 5-48). A relatively small, additional exceedance area appears in the future scenario in the south-central part of the Field. Contour plots of other averaging periods for the PSD Class II scenarios are provided in Appendix C.

Figure 5-47
Smith Field - Existing PSD Class II Scenario
Second Highest 24-hr SO_2 Conc. ($\mu g/m^3$)

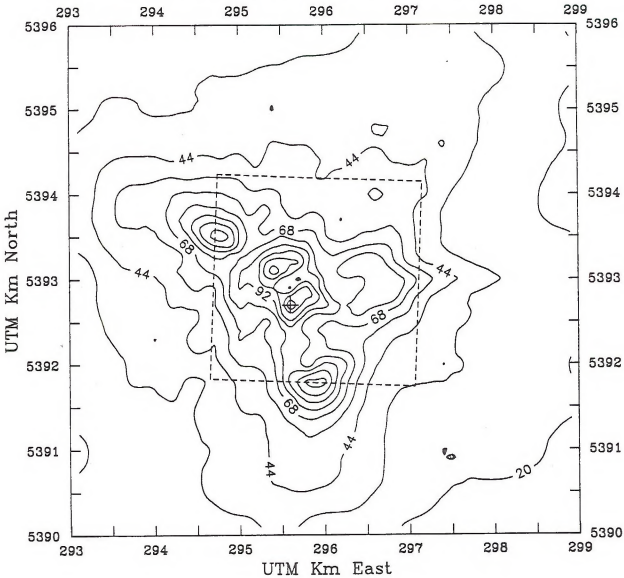


Highest 2nd Highest Concentration (+) = 186
PSD Class II Increment = 91 Contour Interval = 12

Figure 5-48

Smith Field - Future PSD Class II Scenario

Second Highest 24-hr SO_2 Conc. ($\mu g/m^3$)



Highest 2nd Highest Concentration (+) = 187

PSD Class II Increment = 91 Contour Interval = 12

TABLE 5-21
Smith Field
PSD Class II Scenario Modeling Results - SO_2

Averaging Period	Location (UTM km)** East	Location (UTM km)** North	Predicted Concentration	Allowable Increment N.D.	Allowable Increment Federal
Existing PSD Class II Scenario Highest 2nd-Highest Predicted Concentrations (μg/m³)					
3-hour	295.6	5392.7	441.3	512*	512*
24-hour	295.6	5392.7	186.1	91*	91*
Annual	295.6	5392.8	25.9	15	20
Future PSD Class II Scenario Highest 2nd-Highest Predicted Concentrations (μg/m³)					
3-hour	295.6	5392.7	441.3	512*	512*
24-hour	295.6	5392.7	187.1	91*	91*
Annual	295.6	5392.8	30.2	15	20

*One exceedance per year is permitted.
**UTM Zone 14

Normalized-composite plots for the Smith Field existing and future PSD Class II scenarios are provided in Figures 5-49 and 5-50, respectively. As indicated by a comparison of the plots, the exceedance area for the future scenario is much larger than the exceedance area for the existing scenario. As expected, the exceedance area for the future scenario expands to the east and south, where projected future wells are located.

5.1.10.3 Terrain Effects

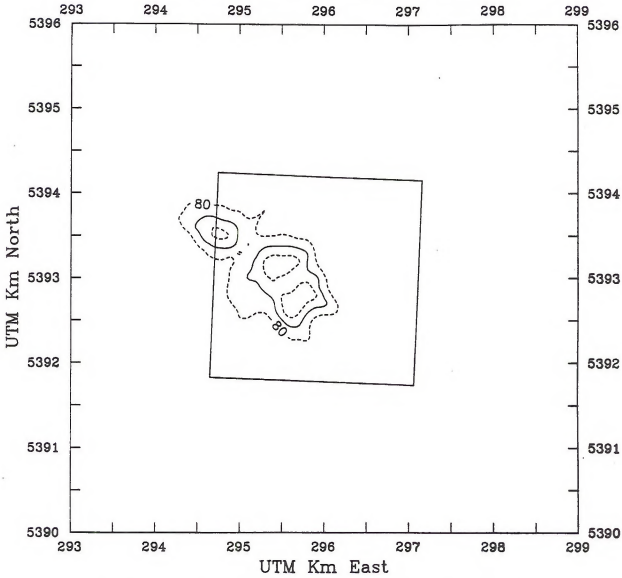
Terrain in the vicinity of the Smith Field is generally flat or gently rolling. It is therefore not expected that terrain influences would significantly alter dispersion modeling results for the Smith Field.

5.1.11 Stanley Field

5.1.11.1 Ambient

Maximum predicted SO_2 concentrations for the Stanley Field ambient scenarios are provided in Table 5-22. As indicated, maximum predicted concentrations are below AAQS for each applicable averaging period for both existing and future scenarios. As was the case of the Smith Field, the similarity of results for existing and future ambient scenarios here implies that maximum predicted concentrations for both scenarios are primarily the result of impact from sources associated with existing wells, and that projected future wells do not have a significant additive impact on model results. Again, higher ambient SO_2 concentrations could have been expected because the Stanley Field is not serviced by a gas-gathering system. The fact that maximum predicted concentrations were safely below AAQS anyway could be due

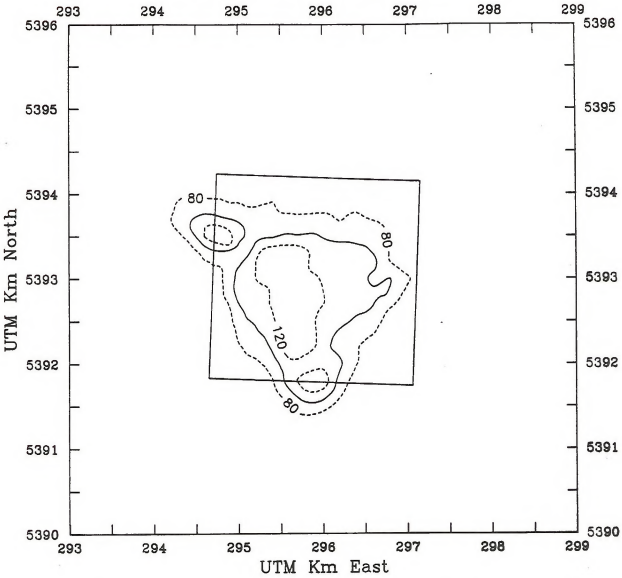
Figure 5-49
Smith Field - Existing PSD Class II Scenario
2nd High SO_2 Conc. Normalized w.r.t. PSD Incr.
Composite of All Averaging Periods



Contour Units = Percent

Contour Interval = 20

Figure 5-50
Smith Field - Future PSD Class II Scenario
2nd High SO_2 Conc. Normalized w.r.t. PSD Incr.
Composite of All Averaging Periods



Contour Units = Percent Contour Interval = 20

to generally low Field production levels, a fairly low well density, and the relatively large stack heights existing in the Field.

TABLE 5-22
Stanley Field
Ambient Scenario Modeling Results - SO_2

Averaging Period	Location (UTM km) East	Location (UTM km) North	Predicted Concentration Modeled	Predicted Concentration Background	Predicted Concentration Total	AAQS N.D.	AAQS Federal
Existing Ambient Scenario Highest Predicted Concentrations (μg/m³)							
1-hour	695.8	5350.8	472.1	13.0	485.1	715	—
3-hour	695.8	5350.6	368.5	11.0	379.5	—	1300*
24-hour	695.7	5350.5	131.8	9.0	140.8	260	365*
Annual	695.9	5350.1	23.6	3.0	26.6	60	80
Future Ambient Scenario Highest Predicted Concentrations (μg/m³)							
1-hour	695.8	5350.8	479.0	13.0	492.0	715	—
3-hour	695.8	5350.6	368.6	11.0	379.6	—	1300*
24-hour	695.7	5350.5	132.2	9.0	141.2	260	365*
Annual	695.9	5350.1	24.3	3.0	27.3	60	80

*One exceedance per year is permitted.

Contour plots of annual average SO_2 concentrations for the Stanley Field existing and future ambient scenarios are provided in Figures 5-51 and 5-52, respectively. The maximum predicted annual average concentration and associated elevated-concentration pocket for both scenarios is located near the relatively congested area of existing wells in the extreme northwest part of the Field. Maximum overall concentrations for other averaging periods were located close to the same area. In comparing Figure 5-52 with Figure 5-51, the additional elevated-concentration pockets associated with future wells are clearly evident.

Contour plots for other averaging periods for Stanley Field ambient scenarios can be found in Appendix C. Contour patterns for other averaging periods tended to be somewhat erratic compared to results for the annual average.

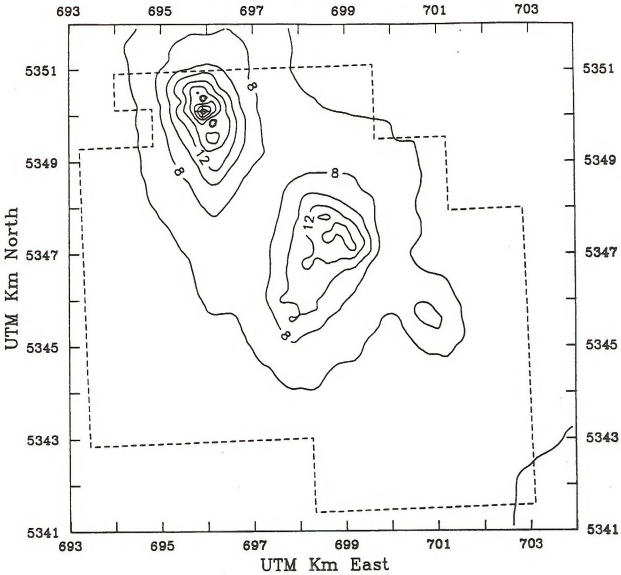
5.1.11.2 PSD Class II

Dispersion modeling results for the Stanley Field PSD Class II scenarios are summarized in Table 5-23. As indicated, predicted HSH concentrations are below allowable increments for the 3-hour averaging period, but exceed allowable increments for the 24-hour and annual averaging periods, for both existing and future scenarios. Again, the similarity of results for existing and future scenarios suggests that the

Figure 5-51

Stanley Field - Existing Ambient Scenario

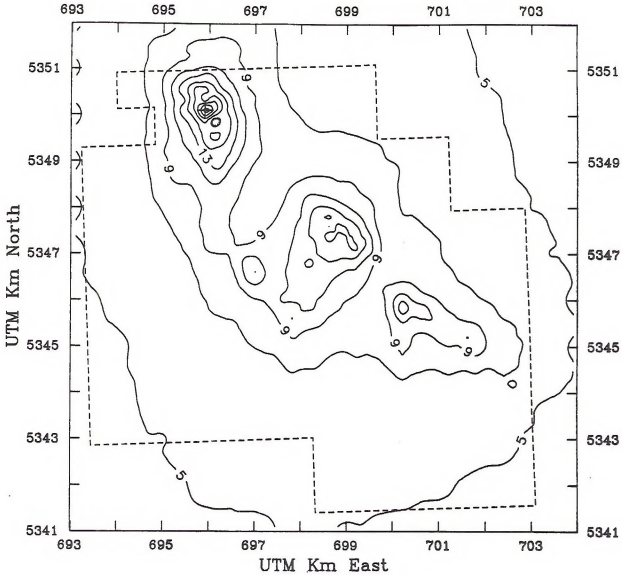
Annual Average SO_2 Concentrations ($\mu g/m^3$)



Highest Concentration (+) = 27

Ambient Air Quality Standard = 60 Contour Interval = 2

Figure 5-52
Stanley Field - Future Ambient Scenario
Annual Average SO_2 Concentrations ($\mu g/m^3$)



Highest Concentration (+) = 27
Ambient Air Quality Standard = 60 Contour Interval = 2

addition of projected future wells to the Field will not significantly further degrade air quality with respect to PSD Class II increments. Predicted exceedances of allowable increments are largely due to both treaters and flares at well numbers 10071 and 9866, but especially due to the short horizontal-treater stack at well 10071.

TABLE 5-23
Stanley Field
PSD Class II Scenario Modeling Results - SO_2

Averaging Period	Location (UTM km) East	Location (UTM km) North	Predicted Concentration	Allowable Increment N.D.	Allowable Increment Federal
Existing PSD Class II Scenario Highest 2nd-Highest Predicted Concentrations (μg/m³)					
3-hour	695.9	5350.6	285.8	512*	512*
24-hour	695.9	5350.6	116.4	91*	91*
Annual	695.9	5350.1	23.4	15	20
Future PSD Class II Scenario Highest 2nd-Highest Predicted Concentrations (μg/m³)					
3-hour	695.9	5350.6	287.5	512*	512*
24-hour	695.9	5350.6	117.6	91*	91*
Annual	695.9	5350.1	24.1	15	20

*One exceedance per year is permitted.

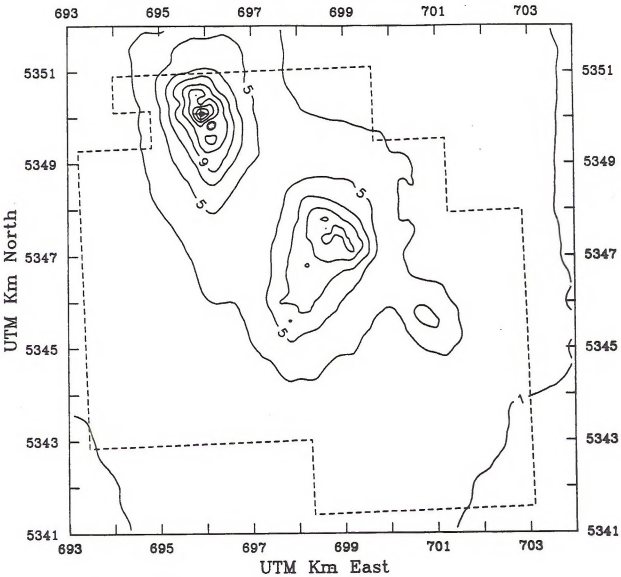
Contour plots of annual average SO_2 concentrations for the Stanley Field existing and future PSD Class II scenarios are provided in Figures 5-53 and 5-54, respectively. Because of the absence of any non-PSD-increment-consuming wells in the Stanley Field, the annual average contour plots for the PSD Class II scenarios are nearly equivalent to the plots for the respective ambient scenarios (Figures 5-51 and 5-52). The primary difference would be the background concentration (3 μg/m³) added to the ambient model results. Again, for the PSD Class II scenarios, maximum concentrations occurred in the extreme northwest part of the field, in the vicinity of existing wells. PSD Class II scenario contour plots for other averaging times are included in Appendix C.

Normalized-composite plots for the Stanley Field existing and future PSD Class II scenarios are included as Figures 5-55 and 5-56, respectively. It is apparent from these plots that the areal extent of Class II increment exceedances is very limited, and that the addition of future wells does not perceptibly increase the size of the exceedance area.

5.1.11.3 Terrain Effects

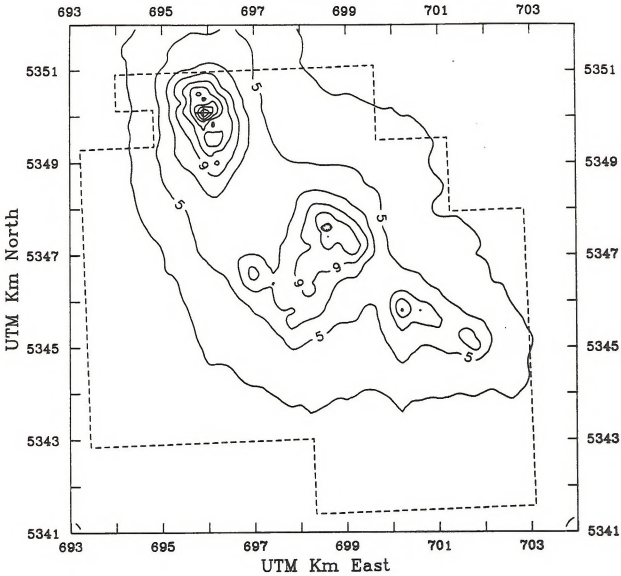
The Stanley Field is typified by gently rolling terrain. As such, it is not expected that terrain influences would significantly alter dispersion modeling results for the Stanley Field.

Figure 5–53
Stanley Field – Existing PSD Class II Scenario
Annual Average SO_2 Concentrations ($\mu g/m^3$)



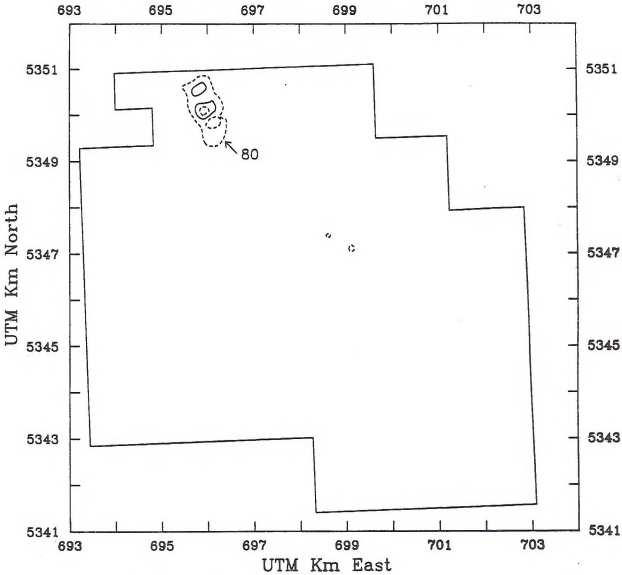
Highest Concentration (+) = 23
PSD Class II Increment = 15 Contour Interval = 2

Figure 5-54
Stanley Field - Future PSD Class II Scenario
Annual Average SO_2 Concentrations ($\mu g/m^3$)



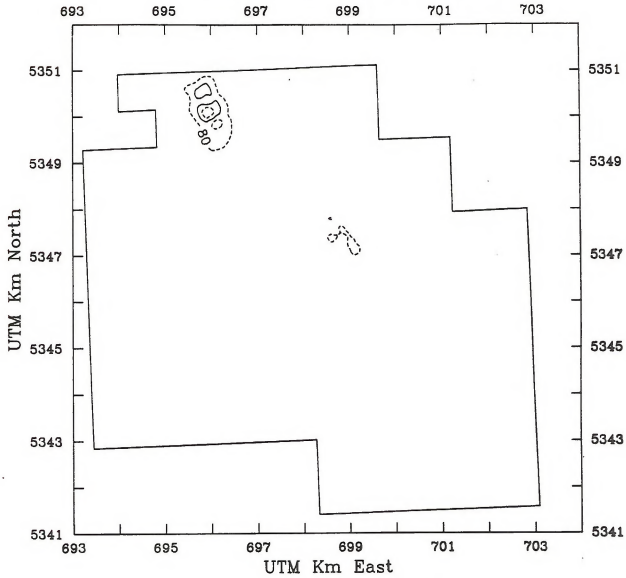
Highest Concentration (+) = 24
PSD Class II Increment = 15 Contour Interval = 2

Figure 5-55
Stanley Field - Existing PSD Class II Scenario
2nd High SO_2 Conc. Normalized w.r.t. PSD Incr.
Composite of All Averaging Periods



Contour Units = Percent Contour Interval = 20

Figure 5-56
Stanley Field - Future PSD Class II Scenario
2nd High SO_2 Conc. Normalized w.r.t. PSD Incr.
Composite of All Averaging Periods



Contour Units = Percent Contour Interval = 20

5.1.12 Whiskey Joe Field

5.1.12.1 Ambient

Maximum predicted SO_2 concentrations for the Whiskey Joe Field ambient scenarios are summarized in Table 5-24. As indicated in Table 5-24, maximum predicted concentrations are well below AAQS for each applicable averaging period for both existing and future scenarios. The highest predicted concentrations for both ambient scenarios are due primarily to impact from sources associated with one existing Whiskey Joe well (10516). Generally, however, the impacts of sources within the Whiskey Joe Field were so low that overall modeling results were largely influenced by sources located outside of the subject field. The air quality impact of sources within the Whiskey Joe Field is low because most wells are tied into a gas-gathering system, and flaring is subsequently very limited. Additionally, H_2S percentages are relatively low in the Whiskey Joe Field.

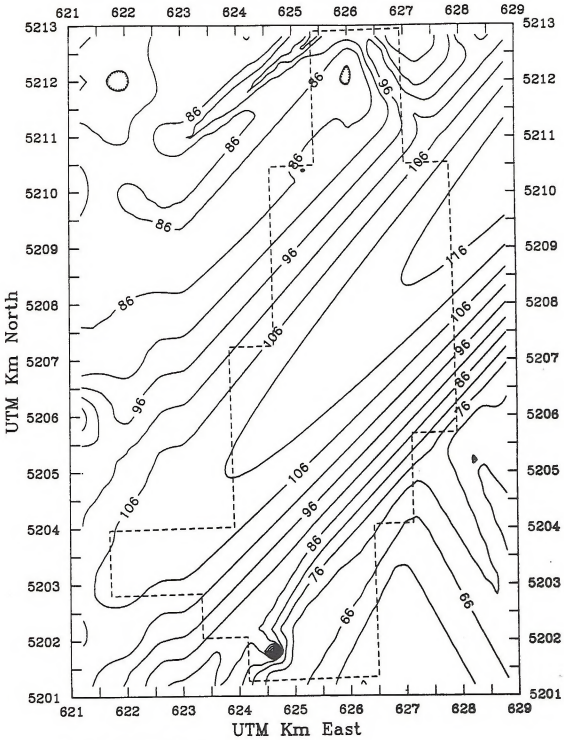
TABLE 5-24
Whiskey Joe Field
Ambient Scenario Modeling Results - SO_2

Averaging Period	Location (UTM km) East	Location (UTM km) North	Predicted Concentration Modeled	Predicted Concentration Background	Predicted Concentration Total	AAQS N.D.	AAQS Federal
Existing Ambient Scenario Highest Predicted Concentrations (μg/m³)							
1-hour	624.6	5201.8	149.5	13.0	162.5	715	—
3-hour	624.6	5201.8	121.3	11.0	132.3	—	1300*
24-hour	624.6	5201.8	48.0	9.0	57.0	260	365*
Annual	626.6	5212.4	4.7	3.0	7.7	60	80
Future Ambient Scenario Highest Predicted Concentrations (μg/m³)							
1-hour	624.6	5201.8	149.5	13.0	162.5	715	—
3-hour	624.6	5201.8	121.3	11.0	132.3	—	1300*
24-hour	624.6	5201.8	48.1	9.0	57.1	260	365*
Annual	625.8	5213.0	5.5	3.0	8.5	60	80

*One exceedance per year is permitted.

A contour plot of highest 1-hour concentrations for the Whiskey Joe Field existing ambient scenario is provided in Figure 5-57. The influence of sources located somewhere northeast of the Field is evident. It appears that the elevated plume-shaped isopleth running diagonally across the Whiskey Joe Field is actually due to sources associated with the Little Knife Field. Also evident in Figure 5-57 is the small pocket of elevated concentrations associated with the overall maximum 1-hour concentration in the extreme southern end of the Field. Again, this pocket is due to the impact from sources associated with one well, and it is reflected in the contour plots for all other averaging times, as well.

Figure 5-57
Whiskey Joe Field - Existing Ambient Scenario
Highest 1-hr SO_2 Concentrations ($\mu g/m^3$)



Highest Concentration (+) = 163
Ambient Air Quality Standard = 715 Contour Interval = 5

Contour plots for the future ambient scenario and for other existing scenario averaging periods can be found in Appendix C. Generally, existing and future scenario plots for corresponding averaging periods are very similar.

5.1.12.2 PSD Class II

Dispersion modeling results for the Whiskey Joe Field PSD Class II scenarios are summarized in Table 5-25. As shown, predicted HSH concentrations are well below allowable increments for each applicable averaging period for both existing and future scenarios. Again, HSH concentrations were due primarily to impact associated with one existing Whiskey Joe well installation (10516), and predicted concentrations overall were generally low because most wells are tied into a gas-gathering system.

TABLE 5-25
Whiskey Joe Field
PSD Class II Scenario Modeling Results - SO_2

Averaging Period	Location (UTM km) East	Location (UTM km) North	Predicted Concentration	Allowable Increment N.D.	Allowable Increment Federal
Existing PSD Class II Scenario Highest 2nd-Highest Predicted Concentrations (μg/m³)					
3-hour	624.6	5201.8	114.5	512*	512*
24-hour	624.6	5201.8	39.9	91*	91*
Annual	626.6	5212.4	4.7	15	20
Future PSD Class II Scenario Highest 2nd-Highest Predicted Concentrations (μg/m³)					
3-hour	624.6	5201.8	114.5	512*	512*
24-hour	624.6	5201.8	40.0	91*	91*
Annual	625.8	5213.0	5.4	15	20

*One exceedance per year is permitted.

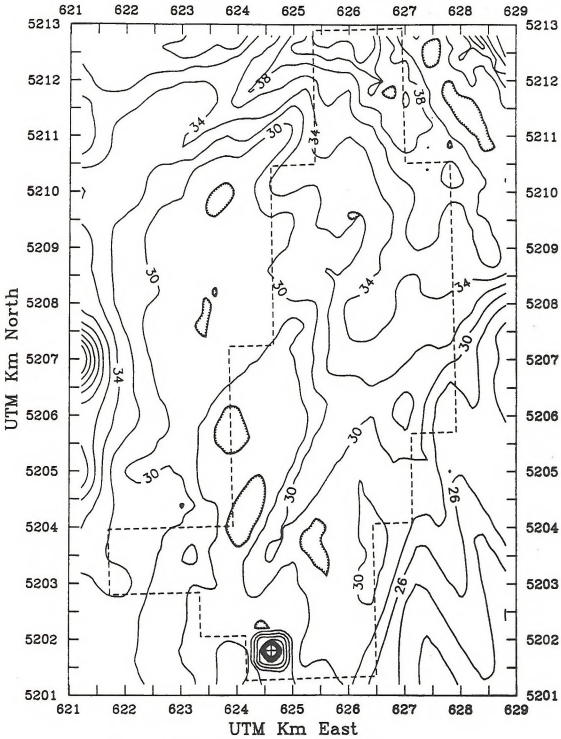
A contour plot of second-highest 3-hour average concentrations for the Whiskey Joe existing PSD Class II scenario is provided in Figure 5-58. The impact of sources outside the Field is not so evident as in the 1-hour ambient scenario results shown in Figure 5-57. However, the second-highest 3-hour concentrations in Figure 5-58 generally increase to the north and west, reflecting impact from the Tree Top and Big Stick Fields, respectively. The elevated-concentration pocket associated with well 10516 is again evident at the southern end of the Field. This elevated-concentration pocket, and the dominant influence of sources located outside the subject field, were characteristic also of contour plots for other averaging periods, which are found in Appendix C.

5.1.12.3 Terrain Effects

Terrain height variations in the vicinity of the Whiskey Joe Field increase from south to north, to the extent that terrain is relatively rugged in the central and northern parts of the Field. Because maximum modeled

Figure 5-58

Whiskey Joe Field – Existing PSD Class II Scenario
Second Highest 3-hr SO_2 Conc. ($\mu g/m^3$)



Highest 2nd Highest Concentration (+) = 115

PSD Class II Increment = 512 Contour Interval = 2

SO_2 concentrations were found in the southern part of the Field, and because maximum concentrations were well below all applicable AAQS or PSD increments, it is not expected that incorporation of terrain effects in the analysis would have a significant impact on results for the Whiskey Joe Field.

5.2 PSD Class I SO_2

Dispersion modeling results for the Williston Basin Study PSD Class I SO_2 scenario were characterized by relatively high predicted concentrations. Exceedances of allowable increments were found in three of the four Class I areas. Moreover, exceedances tended to be widespread throughout these three Class I areas, with predicted HSH concentrations well above designated allowable increment levels (Table 2-2). Because the NDSDH has encountered Class I increment exceedances in previous regulatory modeling analyses, these results were not unexpected.

Specifically, exceedances of allowable Class I increments were found in the Theodore Roosevelt National Park (TRNP) South Unit, North Unit, and Elkhorn Ranch Unit. Exceedances for at least one of the applicable averaging periods were predicted for 16 of the total 17 Class I receptors. Exceedances of the 3-hour allowable increment were found at 16 receptors, exceedances of the 24-hour increment were found at 16 receptors, and exceedances of the annual average increment were predicted for 8 of 17 receptors.

Dispersion modeling results for the PSD Class I scenario are discussed on the basis of individual Class I areas in Sections 5.2.1 through 5.2.4. Results are summarized in tabular form. Note that the regulatory determination of exceedance for 3-hour and 24-hour allowable increments is based on the second-highest predicted concentration, because the regulations allow one exceedance of these increments per year, and one year of meteorological data was used with the models.

Potential terrain effects on model predictions were concluded to be insignificant and not addressed in the presentation of results for Class I areas. The NDSDH has concluded that terrain effects will not be significant (relative to other influences on dispersion) given the typically long transport distances between SO_2 sources and Class I receptors, and thus does not address terrain effects in regulatory Class I modeling analyses.

5.2.1 Theodore Roosevelt National Park - South Unit

PSD Class I modeling results for the TRNP South Unit are summarized in Table 5-26. Results are provided for each receptor to allow some interpretation of the spatial distribution of predicted concentrations. (Refer to Figure 4-23 for receptor locations.) Though regulatory determination of increment exceedance for 3-hour and 24-hour averages is based on the second-highest predicted concentration, the highest concentration is also included for reference.

As shown in Table 5-26, allowable Class I increments for 3-hour and 24-hour averaging periods are exceeded at every receptor in the TRNP South Unit. The annual average increment, however, is not exceeded at any receptor. The HSH 3-hour concentration is 41.6 $\mu g/m^3$ and the HSH 24-hour concentration is 9.7 $\mu g/m^3$. Both of these HSH values were found at Receptor 8, which is located in the northwest end of the South Unit (see Figure 4-23). It is likely that influence of SO_2 emissions from oil and gas facilities in the Theodore Roosevelt (T.R.) Field (located adjacent to the north) was responsible for the HSH values at Receptor 8.

TABLE 5-26
TRNP South Unit
PSD Class I Scenario Modeling Results
(μg/m³)

Receptor Number	3-hour High	3-hour 2nd High	24-hour High	24-hour 2nd High	Annual Average
1	32.9	25.3	9.6	7.8	1.41
2	33.6	30.5	9.0	7.3	1.44
3	35.1	27.3	8.7	8.6	1.31
4	38.2	34.9	9.6	8.8	1.56
5	30.1	29.9	10.9	8.8	1.78
6	31.1	30.6	9.5	9.3	1.85
7	55.2	32.8	10.9	7.5	1.30
8	42.8	41.6	9.8	9.7	1.80

Class I Allowable Increments

Avg.	N.D.	Federal
3-hour*	25	25
24-hour*	5	5
Annual	2	2

*One exceedance per year is permitted.

The overall highest predicted annual average SO_2 concentration for the TRNP South Unit, as shown in Table 5-26, is 1.85 μg/m³. This value occurred at Receptor 6, which is located in the northeast section of the South Unit. Predicted annual average concentrations were fairly uniform across the South Unit. It is thus unlikely that any local source had an exceptional influence on annual average predictions.

In comparing the relative contribution of major PSD sources within 250 km of the TRNP South Unit with that of minor oil and gas sources within 50 km (i.e., the two components of the hybrid modeling approach) to Class I SO_2 predictions, no generalized statement can be made. For the second-highest 3-hour and 24-hour predictions shown in Table 5-26, minor oil and gas sources contributed 90 to 95 percent of the total. However, when major PSD sources alone were modeled in previous regulatory analyses, second-highest predicted concentrations also approached or exceeded Class I allowable increments. Thus, the relative contributions of major PSD sources versus minor oil and gas sources varies from one extreme to the other for the higher 3-hour and 24-hour predictions, and is very dependent on meteorological conditions. This conclusion is also applicable to 3-hour and 24-hour results for the other three Class I areas.

For annual average SO_2 predictions, the relative contributions of major PSD sources and minor oil and gas sources at TRNP South Unit receptors remained more constant. Oil and gas sources generally accounted for 40 to 50 percent of the total. The percentage contribution of oil and gas sources to annual predictions for the TRNP North Unit and Elkhorn Ranch units was somewhat higher.

5.2.2 Theodore Roosevelt National Park - Elkhorn Ranch Unit

PSD Class I modeling results for the TRNP Elkhorn Ranch Unit are summarized in Table 5-27. As shown, predictions exceed allowable increments for all three averaging periods at the single receptor. Predicted annual average and second-highest 24-hour concentrations are significantly greater than any of the corresponding values for TRNP South Unit Receptors. This may be due to the greater density of wells in the vicinity of the Elkhorn Ranch Unit. The generally high predicted concentrations overall at the Elkhorn Ranch Unit are probably the result of influence largely from the Elkhorn Ranch and North Elkhorn Ranch oil and gas fields.

TABLE 5-27
TRNP Elkhorn Ranch Unit
PSD Class I Scenario Modeling Results
($\mu g/m^3$)

Receptor Number	3-hour		24-hour		Annual Average
	High	2nd High	High	2nd High	
9	36.9	36.7	16.1	12.2	2.68

Class I Allowable Increments

Avg.	N.D.	Federal
3-hour*	25	25
24-hour*	5	5
Annual	2	2

*One exceedance per year is permitted.

5.2.3 Theodore Roosevelt National Park - North Unit

PSD Class I modeling results for the TRNP North Unit are summarized in Table 5-28. As indicated, allowable increments for all three averaging periods are exceeded at each receptor. The HSH 3-hour concentration is 41.3 $\mu g/m^3$, the HSH 24-hour concentration is 15.5 $\mu g/m^3$, and the highest annual average concentration is 2.70 $\mu g/m^3$. The HSH 24-hour concentration and highest annual average concentration occurred at Receptor 10 (Figure 4-23), which is located in the extreme southwest part of the North Unit. The HSH 3-hour concentration was found at Receptor 11, which is located in the west-central region of the North Unit.

Overall, predicted SO_2 concentrations are fairly uniform across the TRNP North Unit. Somewhat higher predictions on the west edge of the North Unit (Receptors 10 and 11), however, are probably the result of influence from oil and gas facilities in the Red Wing Creek or Rough Rider Fields (to the west and south, respectively) or the Boxcar Butte or Enron Gas Processing Plants (to the west and northwest, respectively). Predicted concentrations are generally higher at the TRNP North Unit than at the South Unit. This is probably due to greater well density, and typically higher gas H_2S percentages, in the vicinity of the North Unit.

TABLE 5-28
TRNP North Unit
PSD Class I Scenario Modeling Results
(μg/m³)

Receptor Number	3-hour High	3-hour 2nd High	24-hour High	24-hour 2nd High	Annual Average
10	40.8	38.9	17.2	15.5	2.70
11	43.7	41.3	15.0	12.5	2.39
12	38.3	34.0	17.0	15.3	2.39
13	30.0	29.3	13.9	12.4	2.15
14	31.7	31.0	13.3	12.2	2.08
15	31.9	31.7	14.4	12.8	2.37
16	39.6	38.7	14.5	13.2	2.47

Class I Allowable Increments

Avg.	N.D.	Federal
3-hour*	25	25
24-hour*	5	5
Annual	2	2

*One exceedance per year is permitted.

5.2.4 Lostwood National Wilderness Area

PSD Class I modeling results for the Lostwood National Wilderness Area (NWA) are summarized in Table 5-29. As shown, predictions are below allowable increments for all three averaging periods at the single receptor. The relatively low SO_2 predictions for the Lostwood NWA are probably due to lower well density in its immediate vicinity, and its greater distance from major SO_2 sources (i.e., those modeled with MSPUFF).

TABLE 5-29
Lostwood NWA
PSD Class I Scenario Modeling Results
(μg/m³)

Receptor Number	3-hour High	3-hour 2nd High	24-hour High	24-hour 2nd High	Annual Average
17	18.9	17.3	5.2	4.7	0.68

Class I Allowable Increments

Avg.	N.D.	Federal
3-hour*	25	25
24-hour*	5	5
Annual	2	2

*One exceedance per year is permitted.

5.3 Ambient H_2S

Because H_2S predictions were based on a conversion of model results for the ambient SO_2 scenarios, the pattern of 1-hour H_2S projections is predictably similar to 1-hour SO_2 results. Like the SO_2 results, H_2S results were also highly variable among the twelve Study fields. For some fields, predicted H_2S air quality concentrations were low and relatively uniform, while other fields contained pockets of very high H_2S concentrations where predictions greatly exceeded the Ambient Air Quality Standard (AAQS). These high predictions, however, tended to be very localized and, over most of the Study area, model predictions were below the AAQS for both existing and future scenarios.

Some caution must be exercised in interpreting H_2S results. Recall that H_2S concentrations were derived from SO_2 concentrations assuming a treater/flare combustion efficiency of 75 percent. Actual combustion efficiency, however, may deviate significantly from this value. As a result, maximum H_2S concentrations could be higher or lower than those reported here. In addition, areas of exceedance of the H_2S AAQS could be larger or smaller than those denoted in the figures in this Section.

The extent of predicted exceedances of AAQS for H_2S is summarized in Table 5-30. As indicated in Table 5-30, predicted AAQS exceedances for the existing ambient scenario were found in six of the twelve Study fields, while AAQS exceedances for the future ambient scenario were found in seven fields. The Table 5-30 summary may be somewhat misleading in that exceedances tended to be very localized, covering a relatively small fraction of total Study-field area.

TABLE 5-30
Summary of Predicted
Exceedances of AAQS - H_2S

	Ambient Scenarios - Exceedance of AAQS Predicted?	
Field	Existing	Future
Big Stick	No	No
Buffalo Wallow	No	No
Charlson	No	No
Elkhorn Ranch	Yes	Yes
Little Knife	Yes	Yes
Lone Butte	Yes	Yes
Lost Bridge	Yes	Yes
Rough Rider	Yes	Yes
Scairt Woman	No	Yes
Smith	Yes	Yes
Stanley	No	No
Whiskey Joe	No	No

H_2S results for the existing and future ambient scenarios are discussed on a field-by-field basis in Sections 5.3.1 through 5.3.12. Results are presented in tabular form and as contour plots of 1-hour H_2S isopleths. Contour plots for selected fields and scenarios are included and discussed in Section 5.3.1 through 5.3.12.

A complete set of contour plots, for both ambient H_2S scenarios for each Study field, are provided in Appendix D.

Note that comparisons with AAQS for H_2S are based on the second-highest predicted concentrations at each receptor. The second-highest values are used because the State regulations allow one exceedance per year of the 1-hour AAQS for H_2S (see Table 2-1), and one year of meteorological data was used for the modeling analysis from which H_2S concentrations were derived.

The normalized-composite plots which were featured in the presentation of SO_2 modeling results were not prepared for H_2S predictions. The primary benefit of these plots was to allow a composite interpretation of results for all averaging periods. Because the H_2S analysis involved only one averaging period, it was determined that such plots would be of little additional benefit in interpreting H_2S results.

5.3.1 Big Stick Field

Study results for the Big Stick Field ambient H_2S scenarios are summarized in Table 5-31. As shown, the highest second-highest (HSH) predicted H_2S concentration is well below the AAQS for both existing and future scenarios. The HSH concentrations for existing and future scenarios are similar because maximum impact associated with existing wells is concentrated in the southern end of the field, while projected future wells are located primarily in the northern end of the Field. The HSH concentration for the future scenario (co-located with HSH for existing scenario) is thus primarily due to the impact of sources associated with an existing well. The relatively low H_2S ambient concentrations predicted for the Big Stick Field may be a product of the typically low H_2S percentages found in the Field, and the fact that most gas is sold rather than flared.

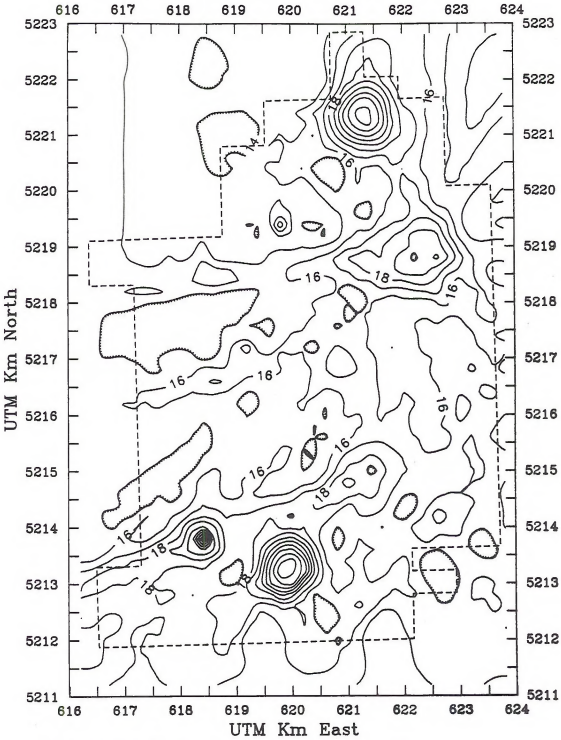
TABLE 5-31
Big Stick Field
Highest 2nd-Highest Predicted 1-hour H_2S Concentrations
($\mu g/m^3$)

	Location (UTM km)		Predicted Concentration			N.D.
Scenario	East	North	Modeled	Background	Total	AAQS*
Existing	618.4	5213.8	27.8	7.0	34.8	70
Future	618.4	5213.8	28.1	7.0	35.1	70

*One exceedance per year is permitted.

The contour plot of second-highest 1-hour H_2S concentrations for the Big Stick existing ambient scenario is provided in Figure 5-59. Again, the contour interval, highest second-highest concentration (location of which is depicted with a "+" symbol within the contoured area), and Ambient Air Quality Standard are noted at the bottom of the Figure. Evident in Figure 5-59 are the pockets of elevated H_2S concentrations in the extreme northern and southern ends of the Field. The highest 1-hour concentration is associated with a very localized area of elevated concentrations in the southwest part of the Field, and are the result of emissions primarily from a central processing facility at well number 7295.

Figure 5-59
Big Stick Field - Existing Ambient Scenario
Second Highest 1-hr H_2S Conc. ($\mu g/m^3$)



Highest 2nd Highest Concentration (+) = 35
Ambient Air Quality Standard = 70 Contour Interval = 1

The contour plot of second-highest 1-hour H_2S concentrations for the Big Stick future scenario can be found in Appendix D. With the exception of two additional elevated-concentration pockets in the east-central part of the Field, which are associated with impact from projected future wells, contour patterns for the future scenario are similar to those of the existing scenario.

Terrain in the vicinity of the Big Stick Field is generally rugged. However, even with incorporation of terrain effects in the dispersion modeling process, highest predicted H_2S concentrations for both scenarios should remain below AAQS.

5.3.2 Buffalo Wallow Field

Predictions for the Buffalo Wallow Field ambient H_2S scenarios are summarized in Table 5-32. As indicated in Table 5-32, HSH concentrations are well below the AAQS for both existing and future scenarios. H_2S emissions and, accordingly, predicted H_2S concentrations are relatively low because most gas from the Buffalo Wallow Field is sold rather than flared. Because of very low well density and subsequent low H_2S emissions for the Field (i.e., one existing well, two future wells), H_2S predictions were dominated by the impact of sources located outside of the Field.

TABLE 5-32
Buffalo Wallow Field
Highest 2nd-Highest Predicted 1-hour H_2S Concentrations
($\mu g/m^3$)

	Location (UTM km)		Predicted Concentration			N.D.
Scenario	East	North	Modeled	Background	Total	AAQS*
Existing	616.4	5280.6	13.4	7.0	20.4	70
Future	616.4	5280.6	18.2	7.0	25.2	70

*One exceedance per year is permitted.

Contour plots of second-highest 1-hour H_2S concentrations for the Buffalo Wallow ambient scenarios are included in Appendix D. The plots include elevated-concentration pockets which distinctly reflect the impacts of the sources associated with the one existing well (existing scenario plot) and two future wells (future scenario plot).

Terrain elevation in the Buffalo Wallow Field increases generally from northwest to southeast, but remains relatively even in the northeast part of the Field where highest predicted H_2S concentrations are located. Incorporation of terrain effects in the dispersion modeling procedure, therefore, would not significantly alter current predictions.

5.3.3 Charlson Field

Highest second-highest predicted 1-hour concentrations for the Charlson Field ambient H_2S scenarios are listed in Table 5-33. As indicated, HSH concentrations are well below the AAQS for both existing and

future scenarios. The HSH concentration for the future scenario is significantly higher than the value for the existing scenario, which indicates that future wells had a significant additive impact on predictions. The HSH concentration for both scenarios actually occurred in the Keene Field, located immediately southwest of the Charlson Field (but included in the receptor region for the Charlson Field). Relatively low H_2S concentrations in the Charlson Field are due to the tie-in of most wells to a gas processing plant (Tioga), and the use of processed gas for treater fuel.

TABLE 5-33
Charlson Field
Highest 2nd-Highest Predicted 1-hour H_2S Concentrations
($\mu g/m^3$)

Scenario	Location (UTM km)		Predicted Concentration			N.D. AAQS*
	East	North	Modeled	Background	Total	
Existing	652.0	5323.8	15.0	7.0	22.0	70
Future	653.4	5323.2	25.8	7.0	32.8	70

*One exceedance per year is permitted.

Contour plots of second-highest 1-hour H_2S concentrations for the Charlson ambient scenarios are included in Appendix D. The influence of Charlson Field well installations is hard to distinguish in these plots because their H_2S emissions are low, and the impact of sources located outside of the Field is relatively large in comparison.

Terrain in the vicinity of the Charlson Field is relatively even in the southern part of the Field, but becomes deeply channeled in the central and northern sections. Because of the extreme terrain height variations in the northern part of the Field, it is difficult to assess the effect of terrain in potentially altering current H_2S predictions in that area. It seems likely, however, that worst-case H_2S predictions would remain within AAQS, even if terrain effects were incorporated in the air quality analysis.

5.3.4 Elkhorn Ranch Field

Study results for the Elkhorn Ranch ambient H_2S scenarios are summarized in Table 5-34. As shown, HSH concentrations exceed AAQS by a substantial margin for both existing and future scenarios. The magnitude of the exceedances is somewhat misleading, however, in that the areal extent of exceedance is very localized. Worst-case H_2S concentrations actually occurred in the North Elkhorn Ranch Field (adjacent to the north boundary of Elkhorn Ranch Field) for both existing and future scenarios. The elevated-concentration area in the North Elkhorn Ranch Field is a result of impact primarily from two relatively short flare stacks for well numbers 9567 and 8671 at a central processing facility on-site of well number 8430.

TABLE 5-34
Elkhorn Ranch Field
Highest 2nd-Highest Predicted 1-hour H_2S Concentrations
($\mu g/m^3$)

Scenario	Location (UTM km)		Predicted Concentration			N.D. AAQS*
	East	North	Modeled	Background	Total	
Existing	614.2	5234.6	225.6	7.0	232.6	70
Future	614.2	5234.6	225.6	7.0	232.6	70

*One exceedance per year is permitted.

Contour plots of second-highest 1-hour H_2S concentrations for the Elkhorn Ranch Field existing and future ambient scenarios are provided in Figures 5-60 and 5-61, respectively. Note that the contour patterns are very similar to the 1-hour results for the Elkhorn Ranch SO_2 ambient scenarios (Figures 5-8 and 5-9). The elevated-H_2S-concentration area in the North Elkhorn Ranch Field (adjacent to the Elkhorn Ranch Field on the north side) is evident for both scenarios. Note that higher-value contours (greater than about 80 $\mu g/m^3$) are left off the plots so as not to obscure the symbol (+) used to designate the location of the HSH concentration.

A second significant area of elevated H_2S concentrations for the future scenario (Figure 5-61) appears in the southwest corner of the Field. This elevated-concentration pocket appears to be the result of impact primarily from two projected future wells (F22 and F23). Additional smaller elevated-concentration pockets associated primarily with existing wells are evident in the plots for both scenarios. Finally, it is evident from Figures 5-60 and 5-61 that the areal extent of H_2S exceedances for the Elkhorn Ranch Field is very limited, and that further development may still be feasible in much of the Field.

The Elkhorn Ranch Field is characterized by continuous rugged terrain, and incorporation of terrain effects in the modeling analysis would likely alter the predictions for H_2S that were discussed above. However, an analysis which addressed terrain effects would probably project higher maximum concentrations and a larger exceedance area for the northern part of the Elkhorn Ranch Field. Western and southern zones of the Elkhorn Ranch Field, where current well density is low and development is most feasible, would not be affected as much.

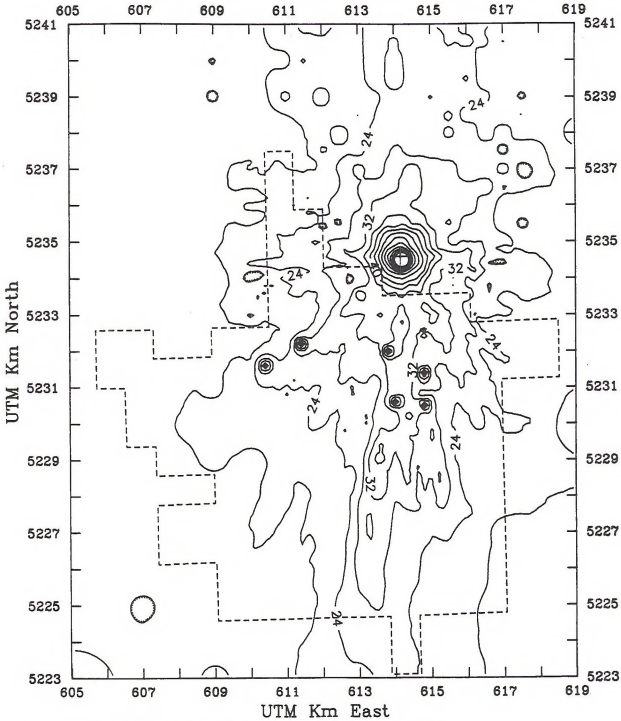
5.3.5 Little Knife Field

Highest second-highest predicted 1-hour concentrations for the Little Knife Field ambient H_2S scenarios are listed in Table 5-35. As shown, HSH concentrations marginally exceed AAQS for both existing and future scenarios. Though most of the gas in the Little Knife Field is channeled to a nearby gas processing plant (Little Knife), relatively high gas H_2S percentages probably accounted for the marginal exceedances. Note that if a slightly higher combustion efficiency had been assumed for the H_2S projection procedure (Section 4.5), it is possible that no H_2S exceedances would have been found for this Field.

Figure 5-60

Elkhorn Ranch Field - Existing Ambient Scenario

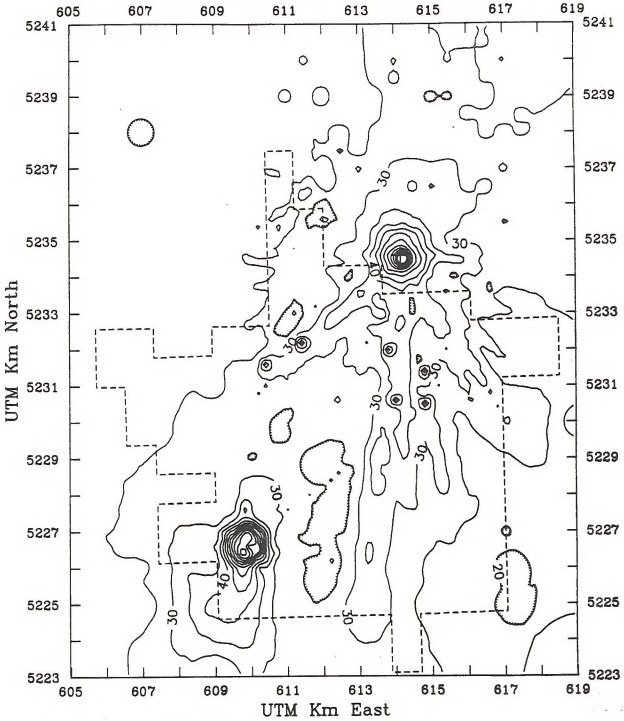
Second Highest 1-hr H_2S Conc. ($\mu g/m^3$)



Highest 2nd Highest Concentration (+) = 233

Ambient Air Quality Standard = 70 Contour Interval = 4

Figure 5-61
Elkhorn Ranch Field - Future Ambient Scenario
Second Highest 1-hr H_2S Conc. ($\mu g/m^3$)



Highest 2nd Highest Concentration (+) = 233
Ambient Air Quality Standard = 70 Contour Interval = 5

TABLE 5-35
Little Knife Field
Highest 2nd-Highest Predicted 1-hour H_2S Concentrations
($\mu g/m^3$)

Scenario	Location (UTM km) East	Location (UTM km) North	Predicted Concentration Modeled	Predicted Concentration Background	Predicted Concentration Total	N.D. AAQS*
Existing	651.9	5237.2	71.7	7.0	78.7	70
Future	651.9	5237.2	71.7	7.0	78.7	70

*One exceedance per year is permitted.

Contour plots of second-highest 1-hour H_2S concentrations for the Little Knife Field existing and future ambient scenarios are provided in Figures 5-62 and 5-63, respectively. For both existing and future scenarios, the configuration of elevated-concentration areas in the Little Knife Field is consistent with the configuration of well locations (Appendix B). As shown in Figure 5-63, the addition of projected future wells to the Field produces a slight increase in overall H_2S concentrations. But the HSH concentration does not change and, on balance, the future wells have a minimal additive impact.

Terrain in the south and central part of the Little Knife Field is gently rolling, but becomes more rugged and defined further north. Predicted H_2S concentrations, particularly in the north end of the Field, would probably be marginally affected by incorporation of terrain influences in the dispersion modeling procedure. Since exceedances of AAQS are already predicted, however, terrain-induced changes in predictions would probably not carry much significance.

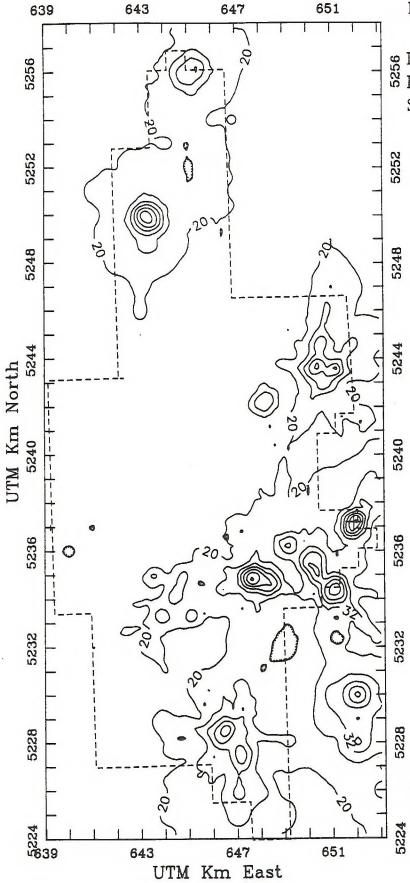
5.3.6 Lone Butte Field

Study results for the Lone Butte Field ambient H_2S scenarios are summarized in Table 5-36. As indicated, predicted 1-hour HSH concentrations exceed the AAQS for both existing and future scenarios. The areal extent of exceedance for the Lone Butte Field was more regional than the localized impacts seen in the results for other fields (e.g., Elkhorn Ranch), but still covered less than a quarter of total Field area. The addition of projected future wells resulted in only a slight increase in size of the exceedance area. Relatively high predicted H_2S concentrations in the Lone Butte Field are probably due to the typically high H_2S percentages of gas in the Field.

Contour plots of second-highest 1-hour H_2S concentrations for the Lone Butte Field existing and future ambient scenarios are provided in Figures 5-64 and 5-65, respectively. The most significant area of elevated concentrations, which includes the highest overall prediction, is seen in the extreme northern end of the Field for both scenarios. A secondary area of elevated concentrations is evident in the center of the Field. Figure 5-65 includes a third distinguishable pocket of elevated H_2S concentrations in the extreme southern end of the Field, which is apparently due primarily to the impact of projected future well installations. Except for this additional elevated-concentration pocket, the effect of the imposition of future wells is not significant. In comparing Figure 5-65 with Figure 5-64, the increase in the exceedance area for the future scenario (70 $\mu g/m^3$ contour) is barely perceptible.

Figure 5-62

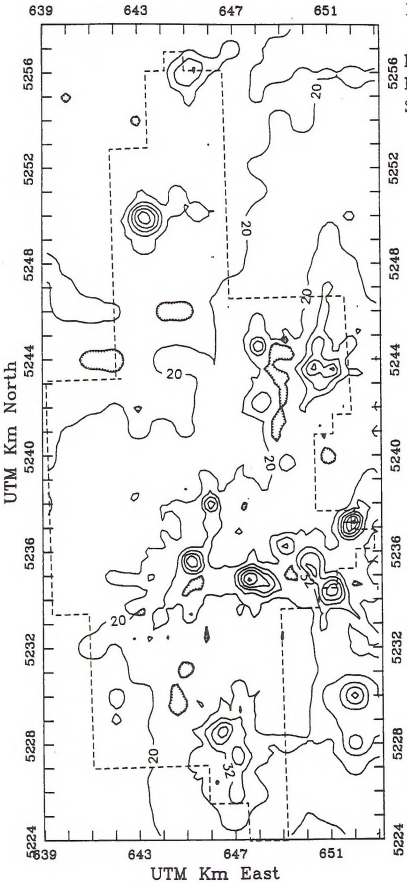
Little Knife Field
Existing Ambient S.
Second Highest 1-hr
H_2S Conc. ($\mu g/m^3$)



Contour Interval = 6
H.S.H. Conc. (+) = 79
AAQS = 70

Figure 5-63

Little Knife Field
Future Ambient S.
Second Highest 1-hr
H_2S Conc. ($\mu g/m^3$)

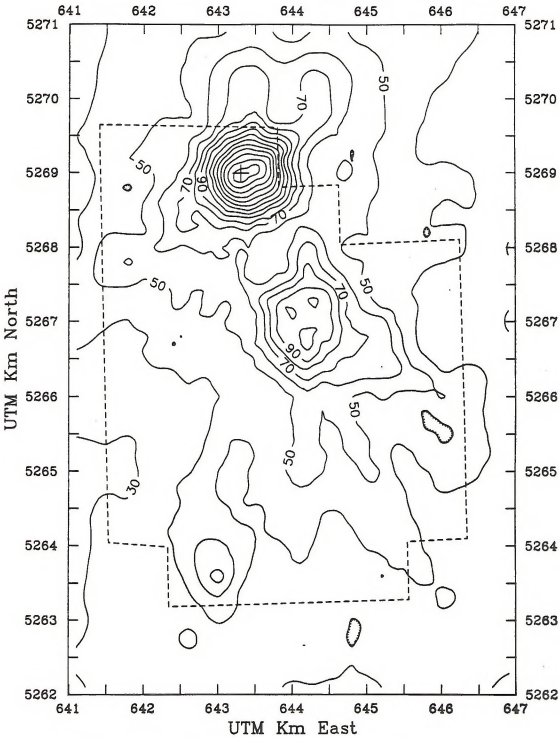


Contour Interval = 6
H.S.H. Conc. (+) = 79
AAQS = 70

Figure 5-64

Lone Butte Field - Existing Ambient Scenario

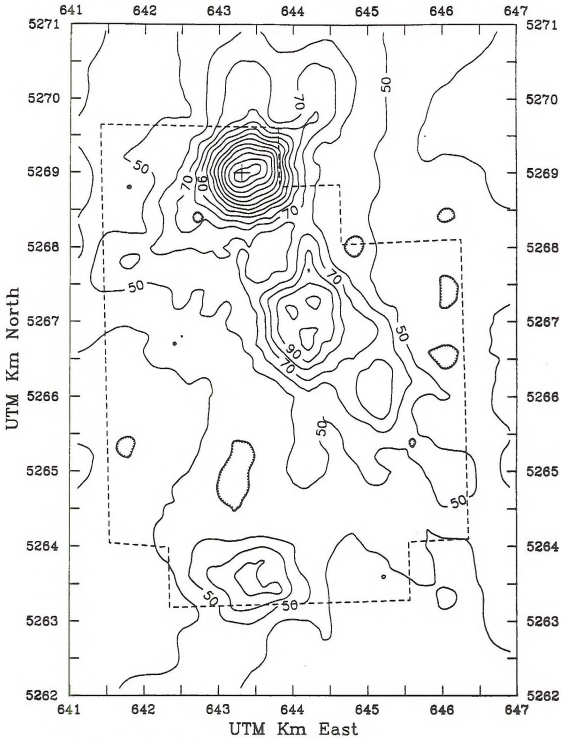
Second Highest 1-hr H_2S Conc. ($\mu g/m^3$)



Highest 2nd Highest Concentration (+) = 189

Ambient Air Quality Standard = 70 Contour Interval = 10

Figure 5-65
Lone Butte Field - Future Ambient Scenario
Second Highest 1-hr H_2S Conc. ($\mu g/m^3$)



Highest 2nd Highest Concentration (+) = 189
Ambient Air Quality Standard = 70 Contour Interval = 10

TABLE 5-36
Lone Butte Field
Highest 2nd-Highest Predicted 1-hour H_2S Concentrations
($\mu g/m^3$)

Scenario	Location (UTM km) East	Location (UTM km) North	Predicted Concentration Modeled	Predicted Concentration Background	Predicted Concentration Total	N.D. AAQS*
Existing	643.3	5269.0	182.3	7.0	189.3	70
Future	643.3	5269.0	182.3	7.0	189.3	70

*One exceedance per year is permitted.

It was indicated in the discussion of ambient and PSD Class II SO_2 results for the Lone Butte Field (Section 5.1.6) that the characteristic very rugged terrain might significantly affect dispersion modeling results, and that an analysis incorporating sophisticated terrain algorithms would be required to properly assess terrain influences. As was the conclusion for the SO_2 results, the magnitude of the highest concentration and the areal extent of exceedance for H_2S predictions would both increase to some degree as a result of the more sophisticated analysis.

5.3.7 Lost Bridge Field

Highest second-highest predicted 1-hour concentrations for the Lost Bridge Field ambient H_2S scenarios are listed in Table 5-37. As indicated, predicted 1-hour HSH concentrations exceed the AAQS by a substantial margin for both existing and future scenarios. The high H_2S concentrations predicted for the Lost Bridge Field are due exclusively to impact from the one, and only, existing well installation (5512). Impact of the projected future wells was virtually imperceptible in comparison.

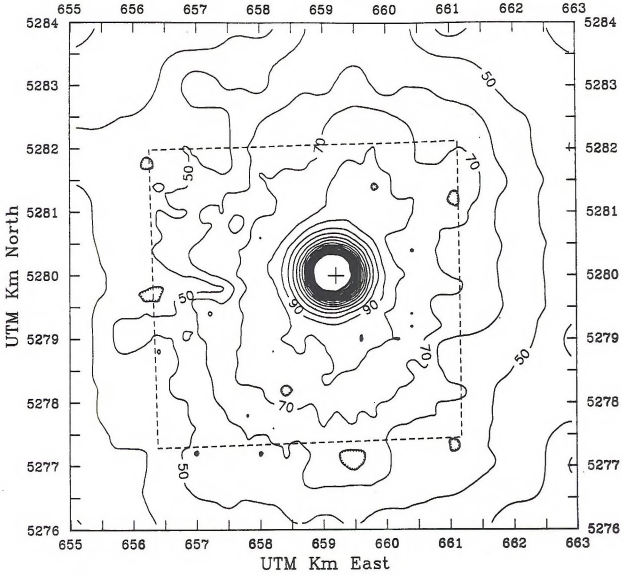
TABLE 5-37
Lost Bridge Field
Highest 2nd-Highest Predicted 1-hour H_2S Concentrations
($\mu g/m^3$)

Scenario	Location (UTM km) East	Location (UTM km) North	Predicted Concentration Modeled	Predicted Concentration Background	Predicted Concentration Total	N.D. AAQS*
Existing	659.2	5280.0	990.2	7.0	997.2	70
Future	659.2	5280.0	991.0	7.0	998.0	70

*One exceedance per year is permitted.

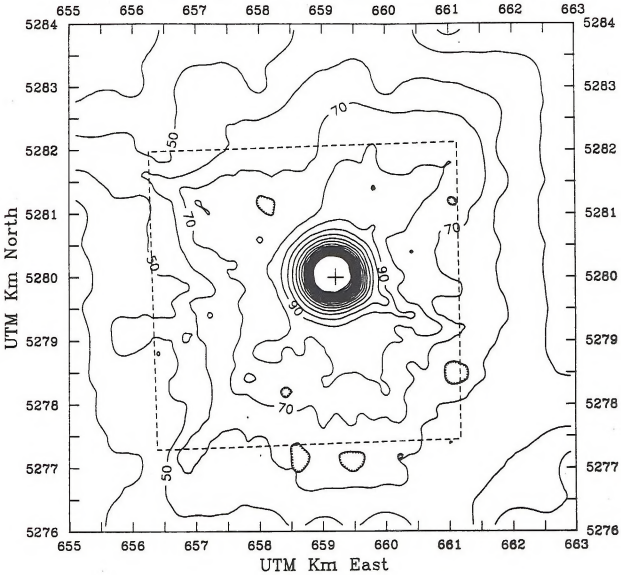
The contour plot of second-highest 1-hour H_2S concentrations for the Lost Bridge existing ambient scenario is provided in Figure 5-66, and the equivalent plot for the future scenario is provided in Figure

Figure 5-66
Lost Bridge Field - Existing Ambient Scenario
Second Highest 1-hr H_2S Conc. ($\mu g/m^3$)



Highest 2nd Highest Concentration (+) = 997
Ambient Air Quality Standard = 70 Contour Interval = 10

Figure 5-67
Lost Bridge Field - Future Ambient Scenario
Second Highest 1-hr H_2S Conc. ($\mu g/m^3$)



Highest 2nd Highest Concentration (+) = 998
Ambient Air Quality Standard = 70 Contour Interval = 10

5-67. The dominant impact of the existing well installation near the center of the Field is evident in both plots. Again, higher-value contours were left off the plots for clarity. The exceedance area extended over a large fraction of the Field for both scenarios. As shown in Figure 5-67, two future wells (F5, F6) located in the northwest part of the Field have the effect of extending the exceedance area (70 $\mu g/m^3$ contour) farther northwest for the future scenario. Otherwise, impact of the addition of projected future wells is not significant.

Because predicted HSH concentrations already greatly exceed AAQS, and because the areal extent of exceedance includes most of the Field, incorporation of terrain effects in the dispersion modeling procedure would not meaningfully change results for the Lost Bridge ambient H_2S scenarios.

5.3.8 Rough Rider Field

Highest second-highest predicted 1-hour concentrations for the Rough Rider Field ambient H_2S scenarios are listed in Table 5-38. Predicted 1-hour HSH concentrations, as shown in Table 5-38, exceed the AAQS for both existing and future scenarios. The predicted HSH concentrations for the Rough Rider Field are quite large relative to the AAQS and, in fact, were the highest for any Study field. Despite the magnitude of the Rough Rider HSH predicted H_2S concentrations, however, the areal extent of AAQS exceedance is very localized, including only a small fraction of total Field area. Relatively high predicted H_2S concentrations are probably due to moderately high H_2S percentages coupled with the generally high well density in the central part of the Field where maximum predictions were found. The extreme maximum value is the result of impact from a ground-level flare at well number 11817.

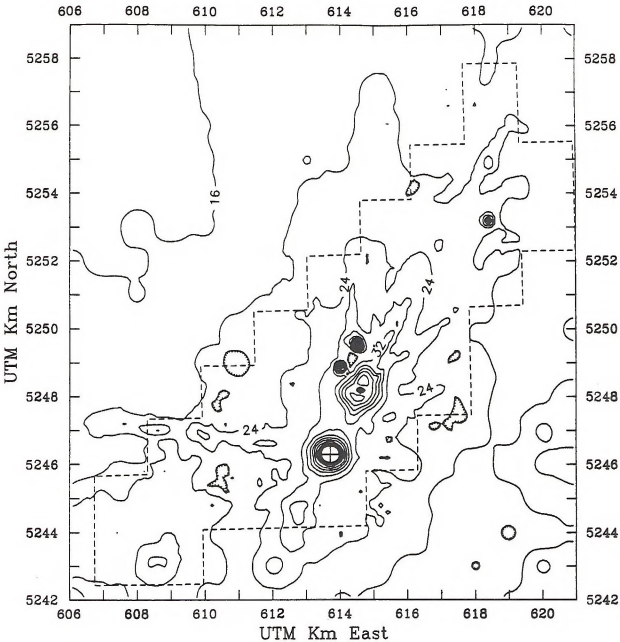
TABLE 5-38
Rough Rider Field
Highest 2nd-Highest Predicted 1-hour H_2S Concentrations
($\mu g/m^3$)

Scenario	Location (UTM km)		Predicted Concentration			N.D.
	East	North	Modeled	Background	Total	AAQS*
Existing	613.7	5246.3	1265.6	7.0	1272.6	70
Future	613.7	5246.3	1266.0	7.0	1273.0	70

*One exceedance per year is permitted.

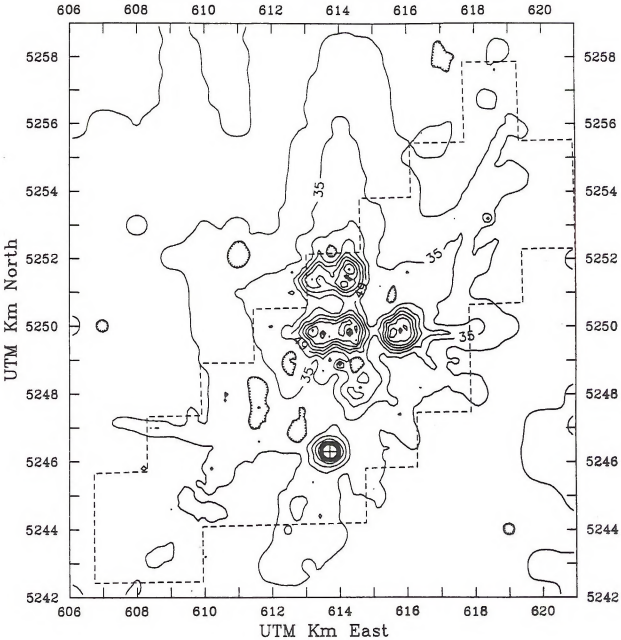
Contour plots of second-highest 1-hour H_2S concentrations for the Rough Rider existing and future ambient scenarios are included as Figures 5-68 and 5-69, respectively. Note that the contour interval for the future scenario plot is larger than the interval for the existing scenario plot. In both plots, the location of the HSH concentration is found in the south-central part of the field, and it is evident that the areal extent of exceedances is very limited. In comparing Figure 5-69 with Figure 5-68, it is evident that the addition of projected future wells to the Rough Rider Field has a significant effect on H_2S predictions. Predicted concentrations averaged across the field are significantly higher, and several additional elevated-concentration pockets (with embedded exceedance areas) are present in the north-central part of the Field

Figure 5-68
Rough Rider Field - Existing Ambient Scenario
Second Highest 1-hr H_2S Conc. ($\mu g/m^3$)



Highest 2nd Highest Concentration (+) = 1273
Ambient Air Quality Standard = 70 Contour Interval = 4

Figure 5-69
Rough Rider Field – Future Ambient Scenario
Second Highest 1-hr H_2S Conc. ($\mu g/m^3$)



Highest 2nd Highest Concentration (+) = 1273
Ambient Air Quality Standard = 70 Contour Interval = 7

for the future scenario. The future exceedance areas due to future wells are somewhat sensitive to the value of combustion efficiency used for the H_2S projection procedure.

Terrain in the Rough Rider Field is typically rugged. Because predicted HSH concentrations already greatly exceed AAQS, incorporation of terrain effects would not meaningfully change results in terms of the worst-case prediction. Inclusion of terrain effects in the analysis, however, could expand the areal extent of predicted exceedances.

5.3.9 Scairt Woman Field

Study results for the Scairt Woman Field ambient H_2S scenarios are summarized in Table 5-39. As shown, the predicted 1-hour HSH concentration is below the AAQS for the existing scenario, but exceeds the AAQS for the future scenario. Again, the extent of exceedances for the future scenario is limited. Results change significantly for the future scenario (compared to the existing scenario) because the Field includes only one existing well, while several future wells were projected. Relatively high predicted H_2S concentrations for the future scenario are probably due to the effects of high gas H_2S percentage for both existing and future wells.

TABLE 5-39
Scairt Woman Field
Highest 2nd-Highest Predicted 1-hour H_2S Concentrations
($\mu g/m^3$)

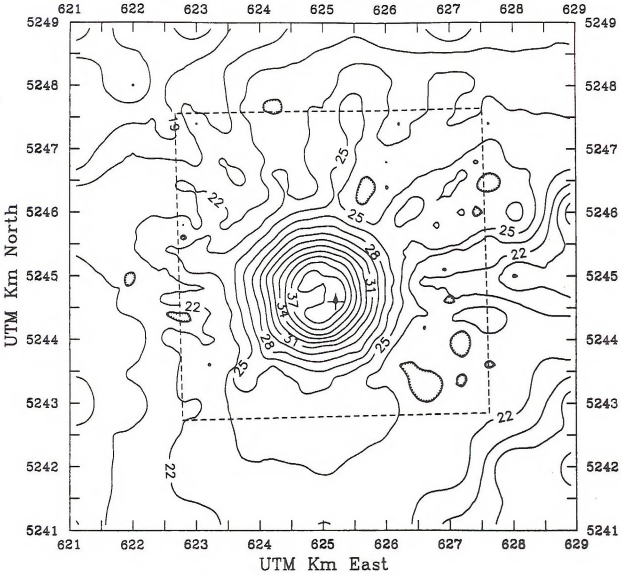
	Location (UTM km)		Predicted Concentration			N.D.
Scenario	East	North	Modeled	Background	Total	AAQS*
Existing	625.2	5244.6	34.8	7.0	41.8	70
Future	626.5	5245.3	114.5	7.0	121.5	70

*One exceedance per year is permitted.

Second-highest 1-hour H_2S concentrations for the Scairt Woman existing and future ambient scenarios are plotted in Figures 5-70 and 5-71, respectively. In comparing the plots, it initially appears that the elevated-concentration pocket has shifted to the east for the future scenario. The comparison is misleading, however, because the contour interval is substantially larger for the future scenario than for the existing scenario. Actually, the impact of the future well installations projected for the east part of the Field (from future wells F6, F7) is so large that it washes out the distinguishable impact of the one existing well (6959) in the future scenario plot. Predicted second-highest H_2S concentrations throughout the Field are significantly larger for the future scenario.

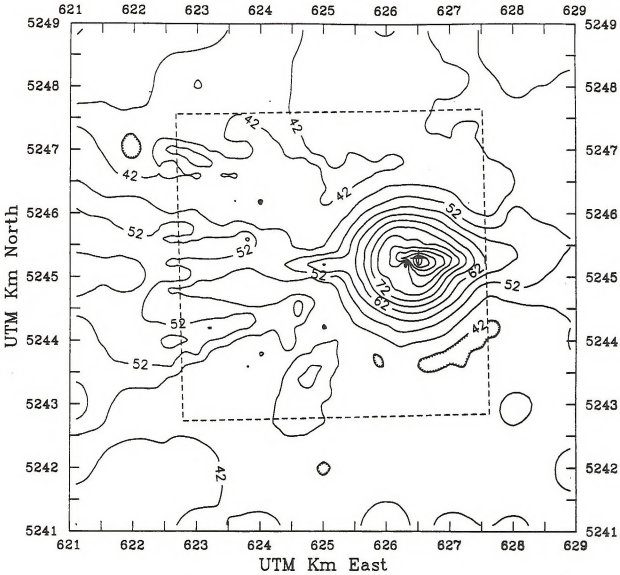
Though terrain in the vicinity of the Scairt Woman Field is generally very rugged, the existing well installation and projected future wells tend to be located at relatively higher elevations among uneven terrain features. Therefore, it is not expected that the effects of terrain on H_2S predictions for the Scairt Woman Field would be very significant.

Figure 5-70
Scairt Woman Field - Existing Ambient Scenario
Second Highest 1-hr H_2S Conc. ($\mu g/m^3$)



Highest 2nd Highest Concentration (+) = 42
Ambient Air Quality Standard = 70 Contour Interval = 1.5

Figure 5-71
Scairt Woman Field - Future Ambient Scenario
Second Highest 1-hr H_2S Conc. ($\mu g/m^3$)



Highest 2nd Highest Concentration (+) = 122
Ambient Air Quality Standard = 70 Contour Interval = 5

5.3.10 Smith Field

Study results for the Smith Field ambient H_2S scenarios are summarized in Table 5-40. As indicated, predicted 1-hour H_2S concentrations marginally exceed the AAQS for both existing and future scenarios. The similarity of HSH concentrations for the existing and future scenarios suggests that future wells will have little additive impact on worst-case H_2S predictions. Somewhat high predicted H_2S concentrations are due to the fact that the Smith Field has no gas-gathering system (i.e., all gas is used for treater fuel or flared), and H_2S percentages of gas in the Field are generally high. It is interesting that the use of tall stacks (treater and flare) in the Smith Field to allow compliance with AAQS for SO_2 (Section 5.1.10.1) did not suffice as far as predicted H_2S compliance. Again, the extent of predicted H_2S exceedances is strongly dependent on the combustion efficiency used in the Study.

TABLE 5-40
Smith Field
Highest 2nd-Highest Predicted 1-hour H_2S Concentrations
($\mu g/m^3$)

Scenario	Location (UTM km)*		Predicted Concentration			N.D.
	East	North	Modeled	Background	Total	AAQS**
Existing	295.9	5392.8	79.6	7.0	86.6	70
Future	295.5	5393.3	80.9	7.0	87.9	70

*UTM Zone 14
**One exceedance per year is permitted.

Contour plots of second-highest 1-hour H_2S concentrations for the Smith existing and future ambient scenarios are provided in Figures 5-72 and 5-73, respectively. Though predicted H_2S concentrations as averaged across the Field are higher for the future scenario, the pattern of elevated contours in the center of the Field, and thus the highest predictions, remain virtually unchanged between scenarios. Note that the location of the HSH concentration, however, does change. The only distinguishable pocket of elevated concentrations associated with a future well (F3) is located in the extreme south-central part of the Field (Figure 5-73). Overall, the addition of future wells appears to have a minimal impact on H_2S predictions.

Terrain in the vicinity of the Smith Field is generally flat or gently rolling. It is therefore not expected that terrain influences would significantly alter H_2S predictions for the Smith Field.

5.3.11 Stanley Field

Highest second-highest predicted 1-hour H_2S concentrations for the Stanley Field ambient scenarios are listed in Table 5-41. As indicated in Table 5-41, predicted HSH concentrations are below the AAQS for both existing and future scenarios. However, if the combustion efficiency used was slightly smaller, exceedances of the H_2S AAQS probably would be predicted. Again, the similarity of results for existing and future ambient scenarios implies that maximum predicted H_2S concentrations for both scenarios are

Figure 5-72

Smith Field - Existing Ambient Scenario

Second Highest 1-hr H_2S Conc. ($\mu g/m^3$)

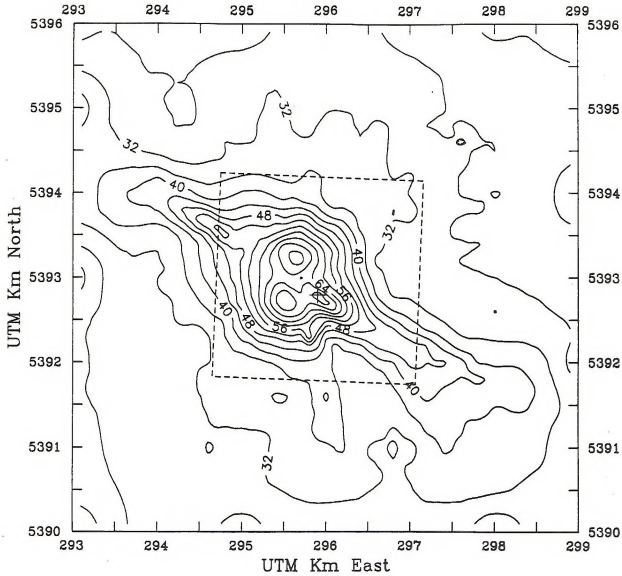
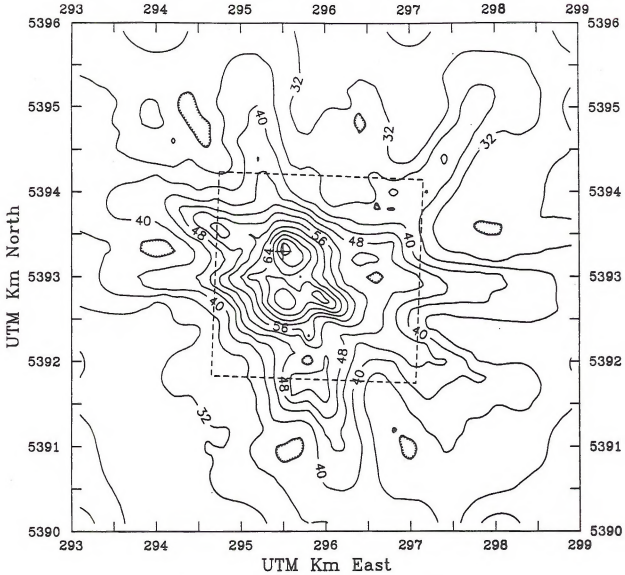


Figure 5-73
Smith Field - Future Ambient Scenario
Second Highest 1-hr H_2S Conc. ($\mu g/m^3$)



Highest 2nd Highest Concentration (+) = 88
Ambient Air Quality Standard = 70 Contour Interval = 4

primarily the result of impact from existing well installations, and that projected future wells do not have a significant additive impact on H_2S predictions. This assertion was confirmed with a comparison of the existing and future scenario contour plots. Low H_2S predictions for the Stanley Field could be due to generally low production levels and a relatively low well density.

TABLE 5-41
Stanley Field
Highest 2nd-Highest Predicted 1-hour H_2S Concentrations
($\mu g/m^3$)

Scenario	Location (UTM km)		Predicted Concentration			N.D.
	East	North	Modeled	Background	Total	AAQS*
Existing	695.8	5350.8	60.5	7.0	67.5	70
Future	695.8	5350.8	61.1	7.0	68.1	70

*One exceedance per year is permitted.

Contour plots of second-highest 1-hour H_2S concentrations for the Stanley Field existing and future ambient H_2S scenarios can be found in Appendix D. Contour patterns for both scenarios are very similar.

Because the Stanley Field is characterized by gently rolling terrain, it is not expected that terrain influences would significantly alter H_2S predictions.

5.3.12 Whiskey Joe Field

Study results for the Whiskey Joe Field ambient H_2S scenarios are summarized in Table 5-42. As indicated, predicted 1-hour HSH concentrations are well below the AAQS for both existing and future scenarios. The HSH concentrations for both scenarios are due primarily to impact from one existing Whiskey Joe well installation (10516). Generally, however, the impacts of H_2S sources within the Whiskey Joe Field were so low that overall results were largely influenced by sources located outside of the subject Field. H_2S emissions from the Whiskey Joe Field are generally low because most wells are tied into a gas-gathering system, and gas burned in the field has a relatively low H_2S percentage.

TABLE 5-42
Whiskey Joe Field
Highest 2nd-Highest Predicted 1-hour H_2S Concentrations
($\mu g/m^3$)

Scenario	Location (UTM km)		Predicted Concentration			N.D.
	East	North	Modeled	Background	Total	AAQS*
Existing	624.6	5201.8	19.5	7.0	26.5	70
Future	624.6	5201.8	19.5	7.0	26.5	70

*One exceedance per year is permitted.

Contour plots of second-highest 1-hour H_2S concentrations for the Whiskey Joe Field existing and future ambient H_2S scenarios can be found in Appendix D. Contour patterns for both plots are dominated by the influence of sources outside the Whiskey Joe Field. The only distinguishable feature which is attributable to a Whiskey Joe well is the elevated-concentration pocket associated with an existing well installation (10516) in the extreme southern end of the Field.

Terrain is more rugged in the northern part of Whiskey Joe Field than in the south. Because maximum predicted H_2S concentrations were found in the southern part of the Field, it is not expected that incorporation of terrain effects in the analysis would have a significant impact on H_2S predictions.

5.4 Meteorological Conditions for Highest Predicted Concentrations

5.4.1 Introduction

For each Study field, the highest predicted concentration for any given scenario is a result of a worst-case combination of source characteristics, meteorological conditions, and receptor distribution. Although the same meteorological data set (Williston 1983) was modeled for all Study fields, the particular meteorological conditions that produce the highest predicted concentrations vary among the different fields because of the differing source characteristics of each field. These worst-case meteorological conditions have been examined and compared for each field to determine if there are consistent patterns of conditions over all Study fields which produce maximum concentrations.

Although the worst-case meteorological conditions were examined for each Study field, some limitations were applied to the analysis. The analysis of meteorological conditions was limited to a consideration of those associated with the highest predicted 1-hour concentration for the existing and future ambient SO_2 scenarios for each Study field. Thus, the analysis included 24 events (n = 24). Because H_2S projections were based on a conversion of 1-hour SO_2 results, the assessment of worst-case meteorological conditions for 1-hour SO_2 results was concluded to be also representative of H_2S. It was concluded beyond the scope of the Study, however, to address meteorological conditions associated with longer-term averages for SO_2.

Again, only the highest concentrations, two for each of the 12 Study fields (i.e., reflecting existing and foreseeable-future scenario), were included in the quantitative discussion of worst-case meteorological conditions. Some second-highest and third-highest concentrations were examined in order to qualitatively judge the effect of increasing sample size, the representativeness of the highest concentrations, and the variability of worst-case meteorological conditions. These second- and third-highest concentrations and their corresponding meteorological conditions were used to make general statements to supplement the quantitative analysis of the results based on highest concentrations.

Each meteorological variable, including temperature, mixing height, wind direction, wind speed, and static stability, is discussed along with some comparisons between different variables. Findings are presented in terms of generalizations over all 12 Study fields; specific statements about each individual field are not usually presented. The SO_2 concentrations analyzed reflect the modeled component, only, of the total concentration (without background added), because only the modeled component is directly related to the meteorological variables (background is constant). Finally, a brief summary is included at the end of the section.

5.4.2 Discussion

One possible cause of high concentrations is restricted vertical mixing due to a very low-level stable layer or inversion. This situation might be expected to occur more often in the winter season or around the time of sunrise when surface temperatures are particularly cold. An examination of the mixing heights at times of maximum concentration indicates that the low-mixing-height scenario above explains only 7 of the 24 cases of highest concentration. The mixing height at maximum concentration varies over a broad range, from 13 m to nearly 3 km. The 24 cases of highest concentration can be subdivided into two groups: the low-mixing-height group, with seven cases of mixing heights below 50 m, and the high-mixing-height group, including the other 17 cases with mixing heights greater than 50 m. There are some major differences between the two groups. The low-mixing-height cases occur during the late fall and winter (October-February), as expected, whereas the high-mixing-height cases occur during summer and early fall (June-September). The vast majority of low-mixing-height cases happen within about one hour after sunrise, whereas high-mixing-height cases occur at many different hours, predominantly during daylight hours.

For the low-mixing-height category, the average mixing height is 29 m and the maximum is 41 m. Low mixing heights are not responsible for producing very high maximum concentrations. The average maximum 1-hour SO_2 concentration for the low-mixing-height cases is only 296 $\mu g/m^3$, and the greatest of the seven is only 577 $\mu g/m^3$, well below the SO_2 1-hour AAQS of 715 $\mu g/m^3$. The highest of all 24 cases of maximum concentration, 10,803 $\mu g/m^3$, is associated with a mixing height of 893 m, clearly too high to significantly restrict vertical mixing.

The ambient air temperature at the surface varies with season and time of day. Maximum concentrations are associated with a large range of temperatures, from -12°C to 34°C. The (wintertime) low-mixing-height cases occur at temperatures of 6°C or colder, and the (summertime) high-mixing-height cases occur at temperatures of 13°C or warmer. Table 5-43 presents the temperature and corresponding stability class vs. the time of day at maximum concentration for only the high-mixing-height cases. (Note that stability class can range from A to G, with A being most unstable and G being most stable; D is considered neutral.)

TABLE 5-43
Temperature (°C) and Stability Class vs. Time of Day (LST) at the Time of Highest 1-Hour SO_2 Concentration for High-Mixing-Height Cases Only

Time of Day (LST)	Temperature (°C)	Stability Class
6 a.m.	13	F
8	22	D
9	22	D
12 p.m.	27	D
1	33	C
2	34	C
3	28	C
4	25	C
8	28	D
12 a.m.	23	D

There are only ten entries because maximum concentrations for different fields or scenarios may occur at the same time. Both temperature and stability class in Table 5-43 exhibit an approximately diurnal cycle. The one case of stable F stability class is associated with a relatively cold early morning surface temperature, while the cases of slightly unstable C stability class are associated with relatively warm afternoon temperatures. The last entry (12:00 a.m.) is the only case that does not occur during daylight hours.

If the normal diurnal and seasonal variability is taken into account, it is apparent that the temperatures at maximum concentration are predominantly near normal or above. Although including cases of second- and third-highest concentrations introduces some below normal temperatures, there is still a strong tendency to have more above normal temperatures than below normal at maximum concentration. A possible explanation for this behavior is that at times of above normal ambient temperatures, the buoyancy of the plume is reduced, as is the effective plume height, allowing the pollutant to be transported to ground level before the plume has dispersed as much as with a higher plume.

The wind speeds observed at times of highest concentration again vary over a broad range. The average wind speed at maximum concentration, 5.4 m/s, is somewhat greater than the climatological average wind speed, 4.5 m/s (Williston). Figure 5-74 displays a frequency distribution of the wind speeds observed at maximum concentration for all 12 Study fields for both existing and future ambient scenarios. As shown, maximum concentrations are most frequently associated with low wind speeds, less than 2 m/s, dropping off rapidly to a fairly constant frequency of occurrence at speeds above about 5 m/s. Including some cases of second- and third-highest concentration broadens the low-wind maximum, with a relatively higher frequency of wind speeds in the range 2-5 m/s. It also decreases the average wind speed somewhat, which suggests a relationship between concentration and wind speeds.

Plotting wind speed against concentration shows a positive correlation, but with a nonlinear, possibly exponential relationship. Figure 5-75 presents wind speed against highest 1-hour SO_2 concentration on a logarithmic scale. The resulting, more linear relationship in the Figure confirms the existence of an exponential relationship between wind speed and maximum SO_2 concentration, with highest, maximum concentrations associated with the highest wind speeds. The diagonal line in Figure 5-75 represents a best-fit exponential curve. The corresponding correlation coefficient, indicated on the Figure, is r=0.827, which is significant at the 0.1% level. Including cases of second- and third-highest concentration weakens the correlation somewhat, but it is still significant.

The positive correlation between wind speed and maximum concentration could be due to the relationship between wind speed and plume height. As wind speed increases, plume rise is reduced, which decreases the plume height at all downwind distances. Thus, the resulting ground-level concentration is higher because the ground is closer to the plume centerline. However, the correlation between wind speed and maximum concentration could also be due to differences in source characteristics among fields. For example, Study fields which experienced maximum concentrations under low wind speeds may have sources with typically lower emission rates than fields which experienced higher maximum concentrations under higher wind speeds. The degree to which plume rise or source characteristics affect the correlation is uncertain without further evaluation.

From the above relationship, the 24 cases of highest concentration can be subdivided based on corresponding observed wind speed into low-, moderate-, and high-wind categories. The three categories are defined subjectively by the following ranges: 0-3.75 m/s for low winds, 3.76-7.5 m/s for moderate winds, and greater than 7.5 m/s for high winds. Additionally, the low-mixing-height cases are excluded from further consideration because they are caused primarily by low mixing heights. Because the low-

Figure 5-74. Wind Speed Observed at Time of Highest Concentration

Existing & Future Ambient Scenarios for All 12 Fields (n=24)

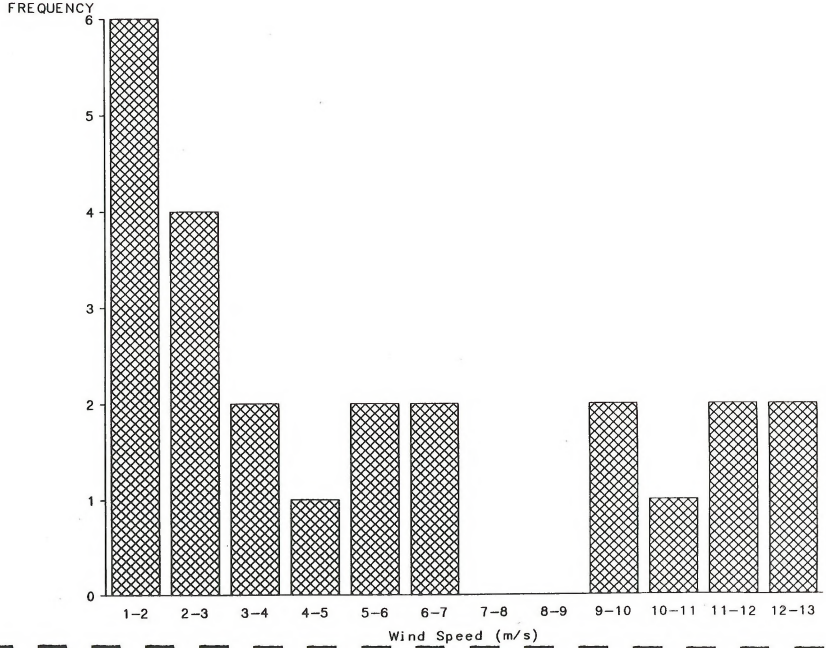
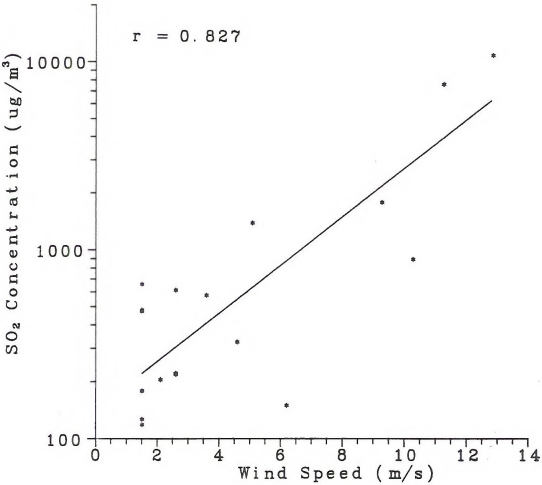


Figure 5-75
Highest 1-hr SO_2 Concentration vs. Wind Speed
For All 12 Study Fields
Existing & Future Ambient Scenarios



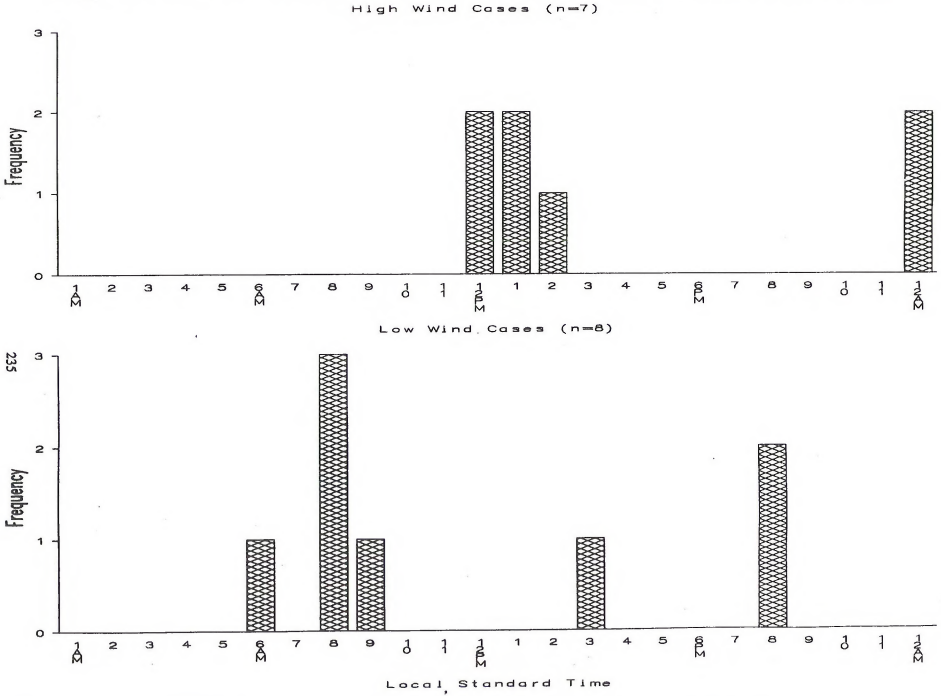
mixing-height group comprises only low- and moderate-wind cases, its exclusion reduces the size of the low-wind category and nearly eliminates the entire moderate-wind category. The average, maximum 1-hour SO_2 concentration over all high-mixing-height, high-wind cases is 5903 $\mu g/m^3$, whereas the average, maximum concentration for all high-mixing-height, low-wind cases is 374 $\mu g/m^3$, exhibiting the positive correlation between highest concentration and wind speed. In addition, there is very little, if any, overlap in concentration between the high-wind, high-concentration category and the low-wind, low-concentration category. The highest, maximum concentration (for all fields), 10,803 $\mu g/m^3$ in Rough Rider Field, results from 12.9 m/s winds, while the lowest, maximum concentration, 127 $\mu g/m^3$ in Charlson Field, is associated with 1.5 m/s winds. The high-wind, maximum concentrations are all greater than 894 $\mu g/m^3$, all above the 1-hour SO_2 AAQS, whereas the low-wind, maximum concentrations are all less than 658 $\mu g/m^3$, all below the 1-hour SO_2 AAQS.

Excluding the low-mixing-height category, high-wind cases of maximum concentration strongly tend to occur at different times of the day than do low-wind cases. Figure 5-76 presents two frequency distributions of the time of the day of the occurrence of maximum concentration, with the high-wind cases plotted on top and the low-wind cases on the bottom. High-wind maxima occur in the early afternoon (12-2 p.m.) and late evening (12 a.m.), while the low-wind maxima occur in the morning within a few hours after sunrise (6-9 a.m.) and in the late afternoon to early evening (3-8 p.m.). Cases of second- and third-highest concentration happen mostly at the same times as do highest concentrations, especially filling in the 3-8 p.m. range of low-wind maxima.

By examining the meteorological conditions preceding and following the occurrence of maximum concentrations, a general pattern of the diurnal cycle associated with maximum concentration becomes evident, which helps explain the results of Figure 5-76. Usually, a warm, stable night with calm or very light winds is followed by a warm, slightly unstable day, which would imply that the sky was probably mostly clear. The increasing solar heating, and consequent destabilizing influence, after sunrise is responsible for the weak winds associated with the morning maximum in Figure 5-76. The reverse is true of the early evening low-wind maximum concentrations. The peak solar heating in early afternoon under slightly unstable conditions helps to produce the strong winds associated with the early afternoon high-wind maximum in Figure 5-76. The remaining strong-wind cases that do not occur in the early afternoon are associated with steady, strong winds, steady temperatures, neutral stability, and probably cloudy skies or the strong winds common after a shift in wind direction. Either case is relatively unaffected by the diurnal pattern of radiational heating and could occur at any time of day.

The influence of wind direction on the occurrence of maximum concentration is neither clear nor strong. The wind direction at maximum concentration seems to be largely dependent on the direction of the source of the high concentrations with respect to the nearest receptor. However, because high concentrations are associated with high wind speeds, there is some evidence that the wind direction at maximum concentration is sometimes related to the wind direction at which strong winds are most frequent. The wind rose for Williston 1983 surface data, reproduced in Figure 4-17, shows that strong winds (greater than 15 mph) are most frequent for southeasterly and also westerly through northerly winds, especially for west and northwest winds. For example, the two highest, existing ambient 1-hour SO_2 concentrations, from Rough Rider and Lost Bridge Fields, both occur when the wind blows from a strong emission source to the nearest receptor. Also, the second- and third-highest (over all receptors in a field), highest (in time) concentrations for Lost Bridge Field occur with strong winds blowing from two directions at which strong winds are relatively infrequent. However, the highest concentration in Rough Rider and Lost Bridge and the second-highest, highest concentration in Rough Rider occur with north, northwest, and west winds, respectively, directions at which strong winds are most common. Examination of the wind directions

Figure 5—76. Time of Day at Maximum Concentration



associated with the highest three concentrations for each of the 12 study fields shows a sizable proportion of southeast or west through north winds.

The static stability of the atmospheric mixed layer has a strong influence on both the occurrence and magnitude of maximum 1-hour concentrations. At the time of maximum concentration, neutral D stability is most common, slightly unstable C stability is also quite common, and only one occurrence of stable F stability is recorded. Neither unstable stability classes (A and B) nor additional occurrences of stable stability classes (E, F, and G) are associated with highest 1-hour concentrations. One second-highest, maximum 1-hour SO_2 concentration, for the Whiskey Joe existing ambient scenario, is associated with very stable G stability (nighttime, light winds), but the corresponding concentration is very low, only 109 $\mu g/m^3$. Low-mixing-height cases are associated mostly with neutral D stability, because they occur primarily within an hour after sunrise when the nocturnal inversion is being disintegrated by solar heating. The effect of stability in high-mixing-height cases depends strongly on wind speed.

The effect of stability on the magnitude of maximum concentrations is related to mixing height and wind speed. Low-mixing-height cases do not exhibit a strong, significant relationship between stability and maximum concentration. High-mixing-height cases do, but must be subdivided into low-, moderate-, and high-wind categories to discern a pattern. Table 5-44 presents the stability class-average maximum 1-hour SO_2 concentration and frequency of occurrence as a function of stability class for low- and high-wind categories for high-mixing-height cases only. There is only one moderate-wind case, so it is not included in the Table. From Table 5-44, it is apparent that at relatively high wind speeds increasing stability is associated with increasing maximum concentrations, whereas at relatively low wind speeds increasing stability is associated with decreasing maximum concentrations.

TABLE 5-44
Class-Average Maximum 1-Hour SO_2 Concentration ($\mu g/m^3$)
and Frequency of Occurrence vs. Stability Class
for Both Low- and High-Wind Categories for
High-Mixing-Height Cases Only

High-Wind Category			
Stability Class	*C*	*D*	
Number of occurrences	3	4	
Class-Average Maximum 1-Hour Concentration ($\mu g/m^3$)	1492	9211	
Low-Wind Category			
Stability Class	*C*	*D*	*F*
Number of occurrences	1	6	1
Class-Average Maximum 1-Hour Concentration ($\mu g/m^3$)	613	375	127

A possible explanation of this result can be based on knowledge of the behavior of the downwind distance to maximum ground-level concentrations from an elevated emission source. Given the 200-meter grid spacing used in this Study, the distance between a source and its nearest receptor can range from 10 m to 280 m. More typical source-nearest receptor distances are estimated to range from 50 m to 150 m. Under high-wind conditions, the plume height is so low that the maximum concentration in the downwind direction may be reached in less than 50 m from the source. Because of the stronger dispersion in unstable vs. neutral stability, maximum downwind concentration will be reached at a shorter distance in unstable conditions than in neutral conditions. Then, concentrations will likewise decrease more rapidly downwind in unstable conditions than in neutral conditions. Therefore, the neutral-stability maximum will lie closer to the nearest receptor than will the unstable maximum, producing higher concentrations in neutral conditions.

In low-wind conditions, the situation is reversed. Under low-wind conditions, the plume height is relatively high, such that the downwind distance to maximum concentrations is typically farther away than the 150 meters to the nearest receptor. The unstable-stability maximum in concentrations still occurs at a shorter downwind distance than does the neutral-stability maximum. Consequently, the unstable maximum will lie closer to the nearest receptor than will the neutral maximum, producing higher concentrations in unstable conditions. Because of the small degree of dispersion in stable F stability, the downwind maximum in stable conditions will lie much farther away than at the nearest receptor. As a result, the concentration at the nearest receptor will be relatively small because of the small amount of pollutant diffused to ground level.

5.4.3 Summary of Mixing-Height and Wind-Speed Categories

The meteorological conditions producing maximum concentrations are now summarized by organizing the basic results into the different categories based on mixing height and wind speed. The temperatures at the time of maximum concentration tend to be warmer than normal. The wind direction at maximum concentration is determined primarily by the direction from the worst source to the nearest receptor and secondarily by the direction at which strong winds are most frequent. Other meteorological variables depend on whether the mixing height is less than or greater than about 50 meters (i.e., low or high).

About one-third of the 24 cases of maximum concentration studied occur primarily because of restricted mixing by low mixing heights. Low-mixing-height cases occur in the late fall and winter, usually within one hour after sunrise. The mixed-layer static stability is usually neutral, not stable, reflecting the breakdown of the nocturnal inversion. Wind speeds are light to moderate, not greater than about 6 m/s. The corresponding maximum 1-hour SO_2 concentrations are relatively low and do not exceed the 1-hour SO_2 AAQS.

The other two-thirds of the 24 cases of maximum concentration occur with relatively high mixing heights. High-mixing-height cases occur in the summer and early fall, primarily in the daytime, and exhibit an approximately diurnal cycle of temperature and stability. The maximum concentrations are strongly correlated with wind speed, with the highest concentrations corresponding to the highest wind speeds. Further results depend on wind speed, so the high-mixing-height cases are subdivided into low-, moderate-, and high-wind categories.

High-wind cases of maximum concentration correspond to relatively high maximum concentrations, all of which exceed the 1-hour SO_2 AAQS. High-wind cases occur mostly in the early afternoon when solar

heating is strongest. Cases not occurring in the early afternoon are associated with high-wind events, often after a sudden wind shift, and can happen at any time of day. High-wind maxima are associated with slightly unstable and neutral stability. Neutral stability produces the highest maximum concentrations, with slightly unstable conditions producing more moderate maximum concentrations.

Low-wind cases correspond to relatively low maximum 1-hour SO_2 concentrations, all of which are below the 1-hour SO_2 AAQS. Low-wind cases occur during the daytime either in the morning within 3-4 hours after sunrise or in the late afternoon to early evening, following the typical diurnal pattern of winds on clear, sunny days. Low-wind maxima are associated with slightly unstable and neutral stability and occasionally with stable stability near sunrise. Neutral stability occurs more often in the morning than in the afternoon, while slightly unstable conditions occur mostly in the afternoon. Slightly unstable conditions produce the highest concentrations (in the low-wind category), with increasing stability producing decreasing concentrations.

5.5 Summary of Results

The Williston Basin Study results which were presented and discussed in Sections 5.1 through 5.4 are summarized here to allow a final, more concise overview of the most significant model predictions. Results for each of the Study scenarios are included.

5.5.1 Ambient Scenarios - SO_2

Ambient SO_2 scenario dispersion modeling results for all twelve Study fields are summarized in Table 5-45. For each Study field, highest predicted SO_2 concentrations are listed for each applicable averaging period for both existing and future ambient scenarios. The applicable, most constraining (State or Federal) AAQS is included at the bottom of each column in the Table.

The predicted concentrations shown in Table 5-45 reflect the diversity in results obtained for the twelve Study fields. Highest predicted concentrations ranged from values which were an order of magnitude below AAQS for some averaging periods at the Buffalo Wallow Field, to an order of magnitude greater than AAQS for some averaging periods at the Rough Rider Field.

Despite the relatively high concentrations predicted for some Study fields, the areal extent of exceedances tended to be very localized, with total exceedance area constituting only a small fraction of the total Study area. Further, localized AAQS exceedance pockets were often attributable primarily to the impact of only one or two well installations, thereby increasing the feasibility of applying mitigating measures to obtain compliance with AAQS. Thus, the Williston Basin Study results suggest that, with respect to ambient levels of SO_2, air quality is generally good in the Study fields, and should remain so even after foreseeable-future development.

TABLE 5-45
Summary of Ambient Scenario Results - SO_2
Highest Predicted Concentrations
($\mu g/m^3$)

Field	Existing Scenario				Future Scenario			
	1-hr	3-hr	24-hr	Ann.	1-hr	3-hr	24-hr	Ann.
Big Stick	231.1	179.1	86.8	14.9	233.8	180.6	89.0	15.8
Buffalo Wallow	131.4	72.4	28.9	6.3	191.3	82.7	45.5	7.6
Charlson	139.6	85.8	41.9	8.4	217.7	161.3	55.5	9.1
Elkhorn Ranch	1802.5	1429.8	444.5	56.1	1802.5	1429.9	446.7	58.3
Little Knife	587.9	510.6	193.8	29.0	589.8	510.6	195.7	29.9
Lone Butte	1404.1	1201.8	510.2	57.1	1404.6	1202.5	512.2	59.1
Lost Bridge	7629.9	6595.0	2641.1	140.1	7637.9	6610.5	2656.1	145.0
Rough Rider	10812.5	5644.6	2918.0	166.1	10816.0	5651.7	2922.0	170.1
Scairt Woman	337.4	231.1	117.6	13.3	907.5	651.8	284.3	28.8
Smith	625.5	462.5	197.4	29.0	670.3	462.5	198.9	33.3
Stanley	485.1	379.5	140.8	26.6	492.0	379.6	141.2	27.3
Whiskey Joe	162.5	132.3	57.0	7.7	162.5	132.3	57.1	8.5
AAQS*	715	1300	260	60	715	1300	260	60

*Most restrictive of Federal or State

5.5.2 PSD Class II Scenarios - SO_2

PSD Class II scenario dispersion modeling results for all twelve Study fields are summarized in Table 5-46. For each Study field, highest second-highest predicted SO_2 concentrations (attributable only to PSD-increment-consuming sources) are listed for each applicable averaging period for both existing and future PSD Class II scenarios. Again, the applicable Class II increment is included at the bottom of each column in the Table. The Table provides highest second-highest predicted 3-hour and 24-hour concentrations because Class II increments for those averaging periods allow one exceedance per year, and one year of meteorological data was used in the modeling analysis. Thus, the regulatory determination of PSD increment exceedance would be based on the highest second-highest predicted concentration.

TABLE 5-46
Summary of PSD Class II Scenario Results - SO_2
Highest 2nd-Highest Predicted Concentrations
($\mu g/m^3$)

Field	Existing Scenario			Future Scenario		
	3-hr	24-hr	Ann.	3-hr	24-hr	Ann.
Big Stick	162.3	71.7	11.8	164.2	75.2	12.7
Buffalo Wallow	49.2	18.8	3.1	59.6	25.2	4.4
Charlson	70.3	29.7	4.7	113.6	44.6	5.3
Elkhorn Ranch	1357.2	429.4	52.6	1357.5	429.7	54.9
Little Knife	413.2	159.7	25.8	413.2	160.1	26.7
Lone Butte	1019.4	382.7	53.7	1019.4	383.3	55.7
Lost Bridge	34.6	9.6	1.4	451.5	164.6	20.2
Rough Rider	5606.8	1890.8	162.8	5608.8	1898.4	166.8
Scairt Woman	207.0	77.2	10.2	599.0	225.9	25.6
Smith	441.3	186.1	25.9	441.3	187.1	30.2
Stanley	285.8	116.4	23.4	287.5	117.6	24.1
Whiskey Joe	114.5	39.9	4.7	114.5	40.0	5.4
Class II Inc.*	512	91	15	512	91	15

*Most restrictive of State or Federal.

Like the ambient scenario results, predicted concentrations for the PSD Class II scenarios displayed a great deal of variability across the twelve Study fields. Predicted increment exceedances for the PSD Class II scenarios, however, were found in a larger number of fields than were AAQS exceedances for the ambient scenarios. Highest second-highest predicted concentrations ranged from values which were a factor of ten greater than allowable increments at the Rough Rider Field to a factor of ten lower than some increments at the Buffalo Wallow Field.

Despite the relatively high concentrations predicted for some Study fields, the areal extent of Class II increment exceedances tended to be limited, but was significantly larger than the extent of exceedances for the corresponding ambient SO_2 scenarios. Predicted increment exceedances for example, covered virtually the entire Lone Butte Field for the future scenario. In some instances, even when the HSH

concentration did not change significantly between scenarios, the areal extent of exceedance was significantly larger for the future scenario. In summary, PSD Class II scenario results suggest that PSD increments may place more of a constraint on future oil field development than will AAQS.

5.5.3 PSD Class I Scenario - SO_2

PSD Class I scenario dispersion modeling results for the four Class I areas are provided in Table 5-47. Again, highest second-highest values are listed because the regulatory interpretation of increment exceedance is based on the highest second-highest predicted concentration. The applicable allowable increment is included at the bottom of the column for each averaging period.

TABLE 5-47
Summary of PSD Class I Scenario Results - SO_2
Highest 2nd-Highest Predicted Concentrations
($\mu g/m^3$)

Class I Area	3-hour	24-hour	Annual
TRNP South Unit	41.6	9.7	1.85
TRNP Elkhorn Ranch Unit	36.7	12.2	2.68
TRNP North Unit	41.3	15.5	2.70
Lostwood NWA	17.3	4.7	0.68
Allowable Increment	25	5	2

The results in Table 5-47 indicate that, with the exception of the annual average increment at the South Unit, allowable increments for all three averaging periods were exceeded at all three TRNP Units. No increments were exceeded, however, at the Lostwood NWA. Exceedances at the TRNP North and South Units (the only Class I areas which include more than one receptor) occurred at every receptor location. These results were not unexpected, because previous Class I modeling analyses conducted by the NDSDH have shown Class I increment exceedances, even when only major SO_2 sources were considered. The Williston Basin Study PSD Class I results suggest that Class I increments could place a major constraint on future well development.

5.5.4 Ambient Scenarios - H_2S

Ambient H_2S scenario predictions for all twelve Study fields are summarized in Table 5-48. Highest second-highest values are listed because the regulatory interpretation of AAQS exceedance for H_2S is based on the highest second-highest predicted concentration. The AAQS is noted at the bottom of the Table.

Because the ambient scenario H_2S results were derived from ambient scenario SO_2 predictions, the pattern of results is expectedly similar. Like ambient SO_2 results, H_2S results also demonstrate great diversity among the twelve Study fields. On the average, worst-case H_2S predictions were higher relative to AAQS than were worst-case SO_2 predictions, and the extent of areal exceedance was larger for H_2S. Still, H_2S

exceedances were generally localized and Study results suggest that air quality with respect to H_2S is generally good. Because of the simplified approach to the derivation of H_2S predictions, however, extra caution should attend the interpretation of H_2S results.

TABLE 5-48
Summary of Ambient Scenario Results - H_2S
Highest 2nd-Highest Predicted Concentrations
($\mu g/m^3$)

Field	Existing Scenario 1-hour average	Future Scenario 1-hour average
Big Stick	34.8	35.1
Buffalo Wallow	20.4	25.2
Charlson	22.0	32.8
Elkhorn Ranch	232.6	232.6
Little Knife	78.7	78.7
Lone Butte	189.3	189.3
Lost Bridge	997.2	998.0
Rough Rider	1272.6	1273.0
Scairt Woman	41.8	121.5
Smith	86.6	87.9
Stanley	67.5	68.1
Whiskey Joe	26.5	26.5
AAQS	70	70

6. CONCLUSIONS AND DISCUSSION OF MITIGATING MEASURES

A Study, known as the Williston Basin Study, has been conducted to determine the air quality impact of existing and foreseeable-future oil and gas production facilities in selected oil fields and PSD Class I areas located in western North Dakota. As part of this Study, an emissions inventory was developed for existing and foreseeable-future well installations in the Study area. State-of-the-art computer dispersion models with representative meteorological data were applied to the emissions inventory to predict ambient concentrations of SO_2 and H_2S. These predictions were subsequently compared with applicable ambient air quality standards and PSD increments.

Conclusions and implications of the Williston Basin Study results are presented in Section 6.1. Since exceedances of ambient air quality standards or PSD increments were predicted for some Study fields, the preparation of conclusions included an assessment of mitigating measures which might be applied to existing well installations to temper or eliminate these exceedances. These potential mitigating measures are discussed in Section 6.2.

6.1 Conclusions

In general, dispersion modeling results for the Williston Basin Study indicated that air quality with respect to ambient air quality standards is relatively good in the Study area. But results showed that air quality with respect to PSD increments is not as good, and may place serious constraints on the siting of future wells in the area until mitigating measures are taken to address existing exceedances. For the most part, the addition of foreseeable-future wells to Study fields (future scenario) did not cause significant additional degradation in modeled air quality with respect to ambient air quality standards or PSD increments.

Specific conclusions were developed regarding implication of Study results in general, implication of results for the existing scenarios, and implication of results for the foreseeable-future scenarios. These conclusions are discussed in Sections 6.1.1 through 6.1.3.

6.1.1 General

- Limitations of the Williston Basin Study (described in Section 3.4) must be considered when interpreting Study results.

- For ambient SO_2, PSD Class II SO_2, and ambient H_2S scenarios, the areal extent of predicted AAQS or PSD increment exceedances tended to be very localized. In general, significant impact from individual well installations did not carry very far and, despite relatively dense spacing in some fields, interaction between wells was minimal. Thus, predicted exceedances were often attributable primarily to the impact of one or two well installations in the vicinity. The significance of this finding is that the feasibility of applying mitigating measures to correct exceedances is enhanced (because fewer wells are involved).

- Williston Basin Study results are probably more credible if interpreted in terms of the areal coverage of predicted exceedance of air quality values, rather than in terms of the absolute magnitude of highest predicted concentrations. Despite the relatively dense receptor grids utilized it is apparent that highest predicted concentrations were still somewhat influenced by receptor location. Influence of receptor spacing on the predicted areal coverage of exceedance, however, was not significant.

- Williston Basin Study results suggest that other oil and gas fields with potential for adverse air quality impact (i.e., high emissions or well density) should be modeled in addition to the twelve Study fields already addressed. Modeling results for these other fields would be necessary to accommodate a comprehensive (State-wide) strategy to mitigate existing air quality value exceedances and plan for future development. Moreover, it would not be consistent to apply mitigative actions or future development restrictions to only the twelve fields currently modeled.

- Due to the lack of an emissions inventory for oil and gas production facilities in the past, and other necessary resources, the NDSDH has not addressed SO_2 emissions associated with PSD-increment-consuming oil well installations in previous regulatory PSD Class I modeling analyses. Results of the Williston Basin Study PSD Class I scenario suggest, however, that the contribution of well installations to predictions at Class I receptors is significant, and that this component should be addressed in future regulatory Class I analyses.

6.1.2 Existing Scenarios

- Williston Basin Study results indicate that existing air quality with respect to ambient air quality standards for SO_2 and H_2S is generally good. Though exceedances of ambient air quality standards were predicted for some fields, and though the magnitude of these exceedances was substantial in some cases, the areal extent of exceedance was often very localized. Therefore, the total area of predicted AAQS exceedance reflects only a small fraction of total Study-field area. Total exceedance area for H_2S was somewhat larger than total exceedance area for SO_2.

- Williston Basin Study results indicate that existing air quality with respect to PSD Class II increments for SO_2 is generally good. Again, exceedances of allowable increments were predicted for some Study fields, but they tended to be localized.

- Williston Basin Study results for the PSD Class I scenario were not favorable. Exceedances of allowable Class I SO_2 increments were widespread throughout the Class I areas, occurring at 16 of 17 receptors. The PSD Class I results could pose a serious constraint to the siting of future wells in the area.

- Mitigating measures to correct existing scenario AAQS and PSD Class II increment exceedances due to oil and gas facilities appear feasible. Potential mitigating measures are discussed in Section 6.2.

- Mitigating measures to correct existing scenario PSD Class I increment exceedances do not appear feasible. These exceedances are being created largely by impact from major PSD sources which were either permitted before Class I increment was used up, or permitted using the Class I variance provision (Chapter 33-15-15) which allows the source to cause exceedances of Class

I increment as long as certain other conditions are met (i.e., demonstration to the Federal Land Manager that emissions from the subject source will have no adverse impact on the air quality-related values (including visibility) of the Class I area, and a demonstration that emissions from the subject source will comply with a relaxed set of increments (325 $\mu g/m^3$ 3-hour, 91 $\mu g/m^3$ 24-hour, 15 $/m^3$ annual average for SO_2)). Thus, there is no action which can be taken specifically with regard to oil and gas facilities which will enable compliance with Class I increments. The NDSDH will consult applicable Federal Land Managers (i.e., Park Service) for alternatives to address the Class I increment exceedances which were predicted in the Williston Basin Study.

6.1.3 Foreseeable-Future Scenarios

- Because existing scenario exceedances of AAQS and PSD increments were predicted, mitigating measures would generally have to be addressed before additional development could actually take place. The potential for additional well development, from the air quality standpoint, can be summarized as follows:

  a) For wells with zero emissions potential (e.g., tied-in to gas-gathering network and treater fired with processed gas or propane), future development is completely unrestricted.

  b) For wells with potential SO_2 and H_2S emissions, but which do not significantly impact (as defined in North Dakota Guideline for Air Quality Modeling Analyses) any Class I area, mitigating measures to correct existing AAQS and PSD Class II exceedances (Section 6.2) would have to be implemented before future development could take place. If such wells are located in fields where no exceedances of AAQS or PSD Class II increments were predicted, however, future development would be relatively unrestricted.

  c) For wells with potential SO_2 and H_2S emissions, and which significantly impact a Class I area, mitigating measures for existing AAQS, PSD Class II, and PSD Class I exceedances would have to be addressed before future development could take place. If such wells are located in fields where no exceedances of AAQS or PSD Class II increments were predicted, only the Class I exceedances would have to be addressed. As indicated above, mitigating measures for Class I exceedances do not appear feasible. Thus, future development of wells in this category (potential SO_2 and H_2S emissions and significantly impacts Class I area) will depend on the outcome of discussions between the NDSDH and the Federal Land Manager.

- The addition of projected foreseeable-future wells to Study-field inventories did not substantially change modeling results with respect to ambient air quality standards for SO_2 and H_2S. Areal extent of exceedances increased marginally for some Study fields, but highest predicted concentrations were nearly the same for most fields (i.e., compared to existing scenario results).

- The addition of projected foreseeable-future wells to Study-field inventories had a somewhat greater effect on PSD Class II increments. New exceedances of PSD increments were found in the Lost Bridge and Scairt Woman Fields (where none were predicted for the existing scenario). The areal extent of exceedance increased significantly for the Lone Butte, Rough Rider, and Smith Fields.

- To a large extent, potential mitigating measures to correct existing scenario AAQS and PSD Class II increment exceedances (Section 6.2) would also eliminate predicted future scenario AAQS and PSD Class II increment exceedances.

6.2 Mitigating Measures

To complete the Williston Basin Study, potential measures to mitigate or eliminate predicted exceedances of AAQS or PSD Class II increments were investigated. For some Study fields, simply increasing treater or flare stack heights would effectively and economically solve the problem of exceedances. Increasing stack height would decrease ground-level concentrations in the immediate vicinity of the facility, and at farther downwind distances (e.g., at the TRNP). In fields with high H_2S content, treaters may have to be fired with propane instead of sour gas, or a gas-sweetening system such as an iron sponge may have to be implemented to remove most of the H_2S from the gas stream before combustion. If a gas processing plant is operating nearby, it may be possible to fire treaters on processed gas from a return line connected to the gas processing plant. For fields with high gas production rates, it may be most effective to connect the affected wells to a gas-gathering system, i.e., sales line, to avoid flaring large amounts of H_2S-contaminated gas. As a last-resort option, it may be necessary to cut back or limit production in order to eliminate some AAQS or PSD increment exceedances. Thus, the investigation of mitigating measures had to consider the operational characteristics for each field. Recommendations regarding mitigating measures are discussed separately for each Study field where predicted exceedances of air quality values were found.

Regarding the use of stack-height increase as a mitigating measure, State regulations[3] stipulate that a pollutant source cannot take credit (for modeling demonstration of air quality standard compliance) for stack height greater than GEP (Good Engineering Practice). However, the regulations include a diminimus GEP stack height provision of 65 meters (about 200 feet). The tallest stacks currently being used with oil and gas processing facilities in North Dakota are about 50-60 feet, well below the diminimus height. Because of problems in constructing and maintaining tall stacks and in operating lease equipment with corrosive, H_2S-contaminated sour gas, use of taller stacks at oil and gas well installations is generally not feasible or economical. Therefore, the diminimus stack height provision of 65 meters does not effectively pose a constraint to the use of stack-height increase as a mitigating measure.

All areas of predicted exceedance of any AAQS or PSD Class II increment were addressed in the investigation of mitigating measures. However, in some cases it was not possible to determine with certainty which sources were responsible for producing the exceedances or the relative contributions when more than one source was involved. Sometimes the exceedance area was so large that it encompassed several well locations and the plotted contour patterns did not readily identify the contributing sources. For these situations, only general recommendations for mitigating measures are discussed. Otherwise, source-specific mitigating actions are suggested for each area of exceedance.

6.2.1 Elkhorn Ranch Field

The primary cause of the worst AAQS exceedances predicted for the Elkhorn Ranch Field (which actually occur in the North Elkhorn Ranch Field), is two short flares, co-located, at a central processing facility on-site of North Elkhorn Ranch well number 8430 (refer to Appendix B for well locations). These flares, servicing well numbers 9567 and 8671, have stack heights of one foot and eight feet, respectively. Raising

these flare stacks significantly would most economically reduce the ground-level impacts, but the additive impact of four treaters located at the same central processing facility must also be accounted for. A relatively small exceedance of PSD Class II increment near well number 7165 could also be mitigated by significantly increasing the treater and flare stack heights at that well site.

Future scenario H_2S AAQS and SO_2 Class II increment exceedances are predicted near projected future wells 22 and 23, which are the only future wells in Elkhorn Ranch Field producing from the Red River pool. The flare at future well 23 makes the largest contribution to the future scenario exceedances. These results suggest that future development in the Red River pool will require the use of tall stacks and possibly other mitigating methods, such as the implementation of an on-site gas-sweetening system. No exceedances are predicted in the vicinity of future wells producing from pools other than Red River, because of the lower H_2S content of their gas.

6.2.2 Little Knife Field

The Little Knife Field has no modeled exceedances of the SO_2 AAQS, but exceedances of the PSD Class II increments and H_2S AAQS were predicted for both existing and future scenarios. The only existing area of exceedance of the H_2S AAQS, near well number 9195, appears to be caused largely by a nine-foot flare stack on-site of well number 9195. Both the treater and flare at future well number 9 contribute to new H_2S exceedances in the future scenario. Simply increasing the stack heights of these facilities should eliminate the Class II and H_2S exceedances.

Flare stacks near areas of SO_2 Class II exceedance (several) have been elevated above ground level, but could be raised an additional amount. Some horizontal-treater stacks are relatively short (14-16 ft.) and could be raised to eliminate Class II exceedances. Because treater emission rates are moderately high and usually much higher than the flare emission rates, other mitigating measures may be desirable for treaters. In the past, operators at Little Knife were allowed to switch from propane to sour gas for use in firing treaters. Switching back to propane for firing treaters would eliminate some exceedances. Another alternative would be to fire treaters on processed gas by connecting return lines from the Little Knife Gas Processing Plant.

6.2.3 Lone Butte Field

The Lone Butte Field model results exhibit exceedances of AAQS and PSD Class II increments for SO_2, and AAQS for H_2S, both in the existing and future scenarios. One reason for this is the high H_2S content of the gas produced from Lone Butte wells. The worst area of exceedances, in the northern part of the field, is caused by the relatively high-emitting, 16-foot horizontal-treater stack at well number 9167. Another 16-foot, horizontal-treater stack at well number 9162 appears to be responsible for exceedances of both H_2S AAQS and SO_2 Class II increments, although an extremely high-emitting flare at nearby well number 9510 may also contribute to these exceedances. Raising the stacks of these two horizontal treaters could eliminate associated exceedances. The large area of PSD Class II exceedances in the central part of Lone Butte Field also could be eliminated by raising all treater stacks significantly.

A secondary area of AAQS and PSD Class II exceedances is produced by two moderately high-emitting, 31-foot treater stacks for well numbers 9062 and 9063 at a central processing facility on-site of well number 9062. An alternate solution for this area of exceedances would be to spatially separate the two

treaters to reduce their interaction, possibly locating the treater for well number 9063 on-site of its own wellhead. Future wells 1 and 2, with their high-emitting treater and flare, are predicted to cause both H_2S AAQS and SO_2 Class II exceedances. Mitigating measures more substantial than just increasing stack heights may be needed for these wells.

The characteristically high emission rates of Lone Butte Field may make it impractical, if not impossible, to increase stack heights enough to meet all applicable standards. Other methods may be necessary to reduce the impact of Lone Butte well installations on the local air quality. Since there is an existing sales line for natural gas in the area, all sour gas could be routed to the Lone Butte Field's existing gas-gathering network (no flaring), and treaters could be fired on propane. If the affected well cannot be connected into the existing sales line, an on-site gas-sweetening system may need to be installed to reduce H_2S content in the gas.

6.2.4 Lost Bridge Field

During the existing scenario Study period (November 1987 - March 1988), the Lost Bridge Field included only one well, number 5512, that had any measurable H_2S content. The relatively high-emitting, three-foot flare stack at this well site is the source of the predicted substantial exceedances of the SO_2 and H_2S AAQS. Raising this short flare stack substantially would eliminate these exceedances. The high flare emission rate for well number 5512 is largely a result of the high H_2S content of its gas, which is produced from the Madison pool.

Future exceedances of the SO_2 PSD Class II Increments and H_2S AAQS are predicted near projected future wells 5, 6, and 12. Of the twelve future wells, only these three cause exceedances because they produce from the high-H_2S Madison and Red River pools, whereas the other nine future wells produce from pools with no measurable H_2S content. As a result, future production from the Madison or Red River pools should be contingent on the use of tall treater and flare stacks. If raising the stacks is not sufficient to eliminate the exceedances, some other method must be found. If it is not possible to connect to a gas sales line, an on-site gas-sweetening system could be used to reduce the H_2S content of the gas produced.

6.2.5 Rough Rider Field

The Rough Rider Field modeling results included exceedances of all SO_2 and H_2S AAQS, and SO_2 Class II increments, both for the existing and future scenarios. The worst area of exceedances surrounds well number 11817 and is caused by the relatively high-emitting, low-level flare stack at that well. Since it is the only ground-level flare with relatively high emissions, it should be sufficient to raise the flare stack at well number 11817 to eliminate the existing ambient SO_2 exceedances. Two other areas of exceedance of the SO_2 Class II increments and the H_2S AAQS are associated with a ground-level flare stack at well number 6403, and a ground-level flare stack and a 14-foot horizontal-treater stack at well number 6566. Raising these stacks would easily eliminate the remaining existing exceedances.

Projected future well installations 4, 5, 6, 10, 11, and 12 from the high-H_2S Red River pool produce PSD Class II increment exceedances for the future scenario, and all six except future well 6 also produce H_2S AAQS exceedances. Development of these Red River wells would require the use of treater and flare stack heights greater than those assumed for this Study, in order to comply with applicable standards. If it is not possible to raise the stacks of well number 11817 and the future Red River wells high enough to satisfy

all air quality standards, it may alternately be possible to tie these wells into the existing gas-gathering system in Rough Rider field to avoid flaring high-H_2S gas.

6.2.6 Scairt Woman Field

The existing configuration of the Scairt Woman Field satisfies all air quality standards. However, foreseeable-future development is predicted to result in exceedances of most, if not all, air quality standards. Co-located future wells 6 and 7 produce exceedances of SO_2 and H_2S AAQS and Class II increments. Future well 5 contributes to a relatively large area of PSD Class II increment exceedances. Future well 7 produces from the high-H_2S Red River pool and future wells 5 and 6 produce from the Gunton pool. Because no valid H_2S percentage for the Scairt Woman Gunton pool was available, it was substituted with the Scairt Woman field-average value from the stratigraphically adjacent Red River pool, which has a high H_2S content. The following recommendations are based on the assumption that the H_2S content of the Gunton pool is similar to that of the Red River pool in Scairt Woman. If the H_2S content of the Gunton pool is later shown to be much lower than that of the Red River pool, the predicted future ambient exceedances may not actually occur.

Although all three future wells 5, 6, and 7 have relatively high emission rates, the future ambient exceedances are largely a consequence of future wells 6 and 7 being co-located. Because two future wells can occupy the same spacing unit if they are from different pools (according to inventory preparation procedure, Section 4.2), future wells 6 and 7 were co-located as a worst-case assumption. If future wells 6 and 7 and their respective flares were placed far enough apart, their predicted ambient exceedances could be eliminated. Also, past gas production rates from the Gunton pool were high enough to potentially warrant the construction of a gas-gathering system which would eliminate flaring of large quantities of gas. Otherwise, an on-site gas-sweetening system could be installed to reduce the H_2S content of the gas prior to its combustion.

6.2.7 Smith Field

No SO_2 ambient exceedances, either existing or future, are predicted for the Smith Field. However, H_2S AAQS and SO_2 PSD Class II increment exceedances are predicted for both existing and future scenarios. One area of existing scenario exceedances is associated with well numbers 11914 and 11946. The moderately high-emitting, 30-foot flare stack at well number 11914 makes the primary contribution to this area of exceedances. Increasing treater and flare stack heights at this installation, especially the flare stack height, may be sufficient to eliminate these exceedances.

Another area of existing exceedances is associated with a central processing facility located near well number 11777 servicing well numbers 11777 and 11902. It is comprised of two 26-foot treater stacks and one 40-foot flare stack, all with moderately high emission rates. Although flaring the gas from both wells through one flare stack enhances the plume rise of the flared gas, it may be advantageous to spatially separate each well's facilities, perhaps to each well's own wellhead site, to avoid concentrating the emissions over such a small area. If this separation of facilities or increasing stack heights is not sufficient to eliminate the existing exceedances, it may be necessary to implement an on-site or regional gas-sweetening system. The nearest existing commercial gas processing plant is far enough away that a sales line would be difficult to justify given current market conditions.

Future wells produce new areas of exceedance of the PSD Class II increments, but not of the H_2S AAQS. Future flares make the greatest contribution to these new exceedances. Constructing tall stacks or using another of the mitigating measures mentioned previously for existing wells could eliminate future Class II exceedances.

6.2.8 Stanley Field

The Stanley Field modeling results exhibited no exceedances of the SO_2 or H_2S AAQS. The only existing area of PSD Class II increment exceedances is caused largely by the 16-foot horizontal-treater stack at well number 10071. Increasing the stack height would be sufficient to eliminate these Class II increment exceedances. Stanley Field future wells do not contribute significantly to Class II exceedances which were predicted for the future scenario, which suggests that predicted future scenario exceedances are also due largely to impact from the treater at existing well number 10071.

7. REFERENCES

1 NDSDH, MSDHES, and BLM, 1987. Cooperative Agreement between North Dakota State Department of Health and Montana State Department of Health & Environmental Science and U.S. Department of the Interior, Bureau of Land Management.

2 North Dakota - North Dakota Air Pollution Control Law. North Dakota State Department of Health and Consolidated Laboratories, Bismarck, ND 58502.

3 NDSDH, 1986 - 1989. North Dakota Air Quality Monitoring Data Summaries 1985 through 1988. North Dakota State Department of Health and Consolidated Laboratories, Bismarck, ND 58502.

4 NDSDH, 1987. Letter from Edward Liebsch, NDSDH, to Mark Stiles, BLM. October 5, 1987.

5 BLM, 1988. Letter from William Krech, BLM, to Dana Mount, NDSDH. January 22, 1988.

6 BLM, 1988. Letter from William Krech, BLM, to Steve Weber, NDSDH. June 23, 1988.

7 NDSDH, 1987. Letter from Edward Liebsch, NDSDH, to Jim Hughes, MSDHES. August 26, 1987.

8 MSDHES, 1989. Letter from Jim Hughes, MSDHES, to Russell Pigors, BLM. May 26, 1989.

9 NDSDH, 1989. Memorandum from Steve Weber to Williston Basin Study File. March 9, 1989.

10 BLM, 1988. Letter from Gene Campbell, BLM, to Ken Wangler, NDSDH. April 14, 1988.

11 BLM, 1989. Letter from William Krech, BLM, to Dana Mount, NDSDH. June 1, 1989.

12 BLM, 1989. Policy reflected in memorandum from William Krech, BLM Dickinson District Manager, to all District employees.

13 EPA, 1986. Guideline on Air Quality Models (Revised). Publication No. EPA-450/2-78-027R, Office of Air Quality Planning and Standards, Research Triangle Park, NC 27711.

14 EPA, 1987. Supplement A to the Guideline on Air Quality Models (Revised). Office of Air Quality Planning and Standards, Research Triangle Park, NC 27711.

15 NDSDH, 1986. North Dakota Guideline for Air Quality Modeling Analyses. North Dakota State Department of Health and Consolidated Laboratories, Bismarck, ND 58502.

16 EPA, 1987. Industrial Source Complex (ISC) Dispersion Model User's Guide - Second Edition (Revised). Publication No. EPA-450/4-88-002a,b, Office of Air Quality Planning and Standards, Research Triangle Park, NC 27711.

17 Bowers, J. F., and A. J. Anderson, 1981. An Evaluation Study for the Industrial Source Complex (ISC) Dispersion Model. Publication No. EPA-450/4-81-002, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711.

18 Pierce, T. E., and D. B. Turner, 1980. User's Guide for MPTER. Publication No. EPA 600/8-80-016, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711.

19 Chico, T., and J. A. Catalano, 1986. Addendum to the User's Guide for MPTER. Publication No. EPA-600/8-86-021, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711.

20 Briggs, G. A., 1971. Some Recent Analyses of Plume Rise Observations. Pages 1029-1032 of the Proceedings of the Second International Clean Air Congress, edited by H. M. Englund and W. T. Berry, Academic Press, NY.

21 Briggs, G. A., 1975. Plume Rise Predictions, Chapter 3 (pp. 59-111) in Lectures on Air Pollution and Environmental Impact Analysis. Duane A. Haugen, editor, American Meteorological Society, Boston, MA.

22 Beychok, M. R., 1979. Fundamentals of Stack Gas Dispersion. Milton R. Beychok, 63 Oak Tree Lane, Irvine, CA 92715.

23 NDSDH, 1983. MSPUFF Mesoscale Air Quality Computer Modeling System. North Dakota State Department of Health and Consolidated Laboratories, Bismarck, ND 58502.

24 Environmental Research and Technology, 1987. Determination of Hydrogen Sulfide Concentrations in the Vicinity of Operating Oil and Gas Wells in the Williston Basin. Environmental Research and Technology, Ft. Collins, CO 80522.

25 Energy and Environmental Measurement Corporation, 1984. Oil Well Flare Inlet and Off Gases Analysis H_2S/SO_2, Eastern Montana Well Sites. Energy and Environmental Measurement Corporation, Billings, MT 59101.

26 NDSDH, 1989. Telephone communication between representatives of NDSDH and Texas Air Control Board.

8. ACRONYMS AND ABBREVIATIONS

AAQS	Ambient Air Quality Standards
BACT	Best Available Control Technology
BLM	U.S. Department of the Interior, Bureau of Land Management
Btu/ft^3	British thermal units per cubic foot
cal/ft^3	calories per cubic foot
cal/sec	calories per second
EPA	U.S. Environmental Protection Agency
g/sec	grams per second
GEP	Good Engineering Practice (stack height)
H_2S	Hydrogen Sulfide
HOC	Heat of combustion
ISCST	Industrial Source Complex Short Term (model)
km	kilometers
LST	Local Standard Time
m	meters
m/s	meters per second
MCFD	thousand cubic feet per day
MPH	miles per hour
MPTER	Multiple Point source with Terrain (model)
MSDHES	Montana State Department of Health and Environmental Sciences
MSPUFF	Dynamic Puff model
NDSDH	North Dakota State Department of Health and Consolidated Laboratories
NWA	National Wilderness Area
NWS	National Weather Service
PSD	Prevention of Significant Deterioration
sec/day	seconds per day
SIC	North Dakota State Industrial Commission
SIP	State Implementation Plan
SO_2	Sulfur Dioxide
TRNP	Theodore Roosevelt National Park
USGS	United States Geological Survey
UTM	Universal Transverse Mercator (coordinate system)
WBS	Williston Basin Study
w.r.t.	with respect to
°C	degrees Celsius
°F	degrees Fahrenheit
°K	degrees Kelvin
µg/m^3	micrograms per cubic meter

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